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of the

American Association *of* Petroleum Geologists

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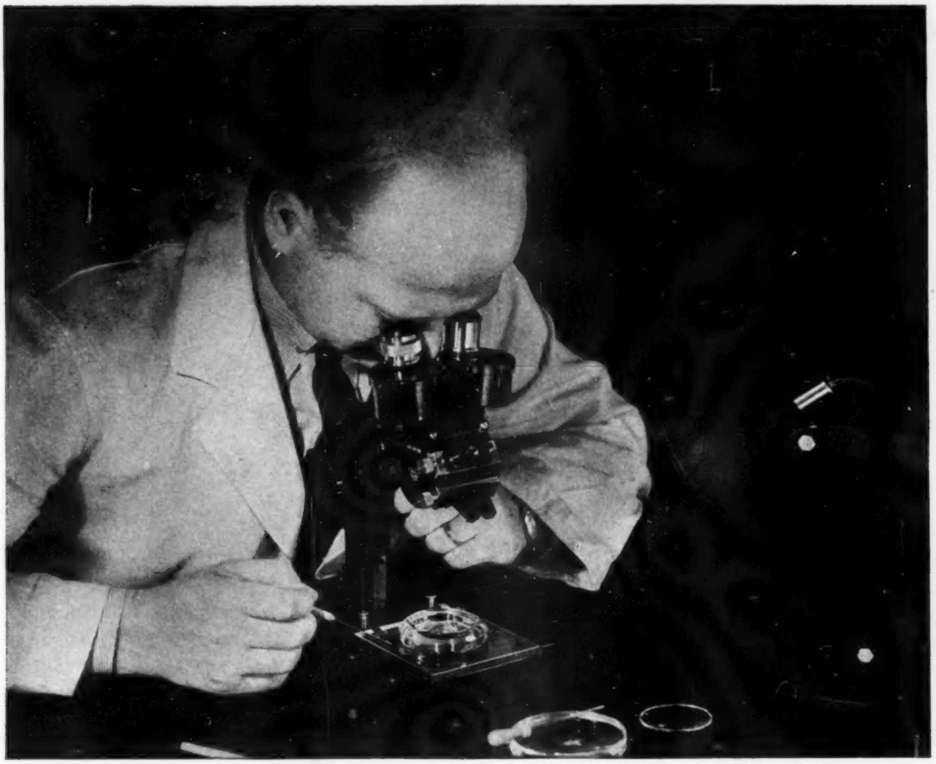

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Volume 23 Number 12

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

DECEMBER, 1939

PERMIAN REDBEDS OF KANSAS[1]

GEORGE H. NORTON[2]
Wichita, Kansas

ABSTRACT

The Permian redbeds of Kansas are re-studied in detail with reference to Cragin's type sections and original classification, to which correlations have been made for more than 40 years, this paper enlarging on an unpublished paper, "Lower Red-Beds of Kansas," abstracted in the *Bulletin* of the American Association of Petroleum Geologists, Vol. 21, No. 12 (December, 1937), pp. 1557–58.

The Cimarron series includes all of the Permian redbeds overlying the salt-bearing and gypsum-bearing gray shales of the Wellington formation. From the base upward, the names and thicknesses of the subdivisions are given.

The two lowermost units, the *Estheria*-bearing Ninnescah shale, 425 feet thick, and the Stone Corral dolomite-anhydrite, 0–6 feet thick (although much thicker in subsurface), have been excluded from Cragin's "Harper sandstones," the latter being here restricted to two higher members: the Chikaskia sandstone, 145 feet thick, and the Kingman sandstone, 80 feet thick. The basal part of the Ninnescah becomes the Garber sandstone in Oklahoma, while its upper part plus the Chikaskia are the equivalent of the type Hennessey of Oklahoma. The Kingman sandstone has been mis-correlated often with the Oklahoma Duncan, a much higher formation.

Cragin's "Salt Plain measures," 275 feet thick and in few places well exposed, has been mis-called "Hennessey shale" in Oklahoma where exposed beneath typical Duncan sandstone. The Cedar Hills sandstone, 180 feet thick, is correlated with the true Duncan of Oklahoma, while the selenite-veined Flower-pot shales, 190 feet thick, have been called Chickasha in Oklahoma. The name "Nippewalla" is suggested for the group of formations lying between the Stone Corral and Blaine evaporites.

Cragin's "Cave Creek formation" is identical with the Blaine formation of Oklahoma, is 84 feet thick, and is divided upward into four beds of gypsum: Medicine Lodge; Nescatunga, a bed in Cragin's "Jenkins clay"; Shimer ("Lovedale" of Noel Evans); and Haskew. Where these gypsums are well developed, only 15 feet of Cragin's Dog Creek shales separate them from the Whitehorse sandstone. At Dog Creek, the type locality, however, with the three upper beds absent because of solution, the separating clays to the base of the "Jenkins" have been included in the 53 feet of Dog Creek shales, the highest unit of Cragin's Salt Fork division of the Cimarron series.

From the base upward, the Kiger division begins with the Whitehorse sandstone, a formation 265 feet thick, the name replacing Cragin's "Red Bluff" (pre-occupied and dropped). It falls into four natural subdivisions or members: Marlow sandstone, 110

[1] Read before the Association at Oklahoma City, March 22, 1939. Manuscript received, June 30, 1939. New names of units of the upper Permian of Kansas used in this paper, namely, Milan, Ninnescah, Runnymede, Stone Corral, Chikaskia, Kingman, Nippewalla, and Nescatunga, are available for this use according to the records of the committee on geologic names, of the United States Geological Survey.

[2] Geologist, The Atlantic Refining Company.

feet thick; Relay Creek dolomites with their included veined sandy shales, 22 feet thick; an even-bedded sandstone, 100 feet thick; and a red shale member, 38 feet thick, with local thin dolomites at middle and base, the last two being equivalent to the Rush Springs-Cloud Chief of Oklahoma, although Cloud Chief gypsums are not recognized in Kansas. No "channel-sands" of the type Verden or type Whitehorse facies of the Marlow have been noted in Kansas, although calcareous, cross-bedded sandstones are found associated with the Relay Creek dolomites.

Capping the Whitehorse sandstone, commonly in a bold scarp, is the "Day Creek dolomite" of Cragin, a single bed of dense, in many places cherty, dolomite 2 feet thick. This bed in turn is overlain by gray and red shales ("Hackberry shales" of Cragin, name pre-occupied, dropped) and "Big Basin sandstone," totalling 65 feet, previously combined under the latter name, which are probably correlative with the lower beds of the Quartermaster formation (restricted) of Oklahoma, these beds terminating the Kansas redbed exposures, with the possible exception of a small exposure in Morton County, not studied by the writer, which is mapped as Triassic by the Kansas State Geological Survey.

Possible horizons of unconformity have been studied critically, the evidence indicating nothing greater than local disconformity, the more pronounced stratigraphic abnormalities ordinarily due to removal of soluble beds by ground waters, resulting in slumpage and collapse-brecciation of the overburden, a condition to be expected of beds in contact with the major dolomite-anhydrite formations, which are the Stone Corral, the Blaine-Dog Creek, and the Day Creek. The excellence of these evaporite formations as key horizons in redbed stratigraphy is emphasized in contrast to the variable lithology of the intervening red siltstones and their included lenses of rounded, frosted, orange-polished or micaceous sandstones, on which scant dependence can be placed, as shown on subsurface cross sections.

A cross section depicts a progressive wedging-out of the various members of the Wellington and Harper formations westward against the Sierra Grande arch of eastern Colorado, where beds of approximate Salt Plain age rest on beds near the top of the Pennsylvanian (Wabaunsee) as accepted by the Kansas Geological Survey, the one real unconformity of regional significance discovered.

Introduction

The redbeds of the southwest have interested explorers and geologists since the days of Marcou, as cited by Marcy,[3] but the first studies of these interesting and brightly colored strata were published by St. John[4] in 1887, referring them doubtfully to the Triassic.

Nine years later Cragin[5] published his classification, laying the foundations of redbed stratigraphy in the mid-continental area. That these foundations were "well and truly laid" is attested by the fact that his classification, with few important changes, still serves after 40 years as a satisfactory basis for the subdivision of the Cimarron redbeds.

Field mapping for the delineation of geologic structure on the surface beds, core-drilling, and the drilling of many tests for oil in the last 10 years, have greatly increased the information concerning these

[3] R. B. Marcy, *Exploration on the Red River of Louisiana in the Year 1852* (Washington, D. C., 1854), pp. 1–286.

[4] O. H. St. John, "Notes on the Geology of Southwestern Kansas," *Kansas State Board Agric. Bien. Rept. 5* (1887), pp. 132–52.

[5] F. W. Cragin, "The Permian System in Kansas," *Colorado Coll. Studies Bull. 6* (1896), pp. 1–48.

beds, much of which is common knowledge, and which has altered some of the geologic conceptions previously generally entertained. It is the purpose of this paper to report the new facts discovered, and to describe in necessary detail, and with accurate measurements, the individual rock units of the redbed sequence, on which correlations with the strata of adjoining and near-by states must be based. Cragin's type localities have been carefully examined and his names, insofar as possible, have been used to designate those strata which the writer believes Cragin to have thus intended. Where further subdivision appeared desirable, the new subdivisions have been described as members to keep them in the framework of the original classification. Inasmuch as the two lower units of his "Harper sandstones" deserve formational rank, however, the Harper is restricted in this paper to exclude them and the name "Harper" is to be confined exclusively to the upper, more predominantly sandstone, members.

Combined surface and subsurface cross sections show the mutual relationships of these beds and their correlations with equivalent strata in Colorado and Oklahoma, where, particularly in the latter, judged by the quantity of conflicting published opinion, these strata appear to be more complex, a factor which may have influenced Cragin in basing his classification in Kansas, a logical place of beginning.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the many helpful suggestions received in the past 10 years from many co-workers in Kansas whose contributions can not be specifically mentioned, but who have ever been willing to give assistance. It must be understood that the information here gathered and the ideas expressed are the sum of the labors of many workers in the field, their published and unpublished opinions borrowed, with or without thanks, and converted to this use. He is particularly indebted to William L. Ainsworth for early information as to the true correlation of the Stone Corral formation, to Forrest E. Wimbish for the location of the best exposure of the Chikaskia member of the Harper, to Payton W. Anderson, Vaughn W. Russom, and D. A. Holm for comparing information on the Salt Plain, Cedar Hills, and Flower-pot sections, and to Howard S. Bryant for the labor of reading and criticizing this manuscript. Thanks are due the State Geological Survey of Kansas for access to an unpublished manuscript and various other information. The permission of The Atlantic Refining Company in allowing the publication of the material here presented is deeply appreciated by the writer.

PREVIOUS WORK

Following the publication of Cragin's classification, amended in a later paper,[6] a good summary of the early work was made by Prosser.[7]

A few years later Gould[8] described the Permian fossils of the beds, and still later he[9] and others[10] described and partially reclassified the Oklahoma equivalents of the Kansas strata, using other names for the most part, because of the altered lithology of some beds and uncertainty of their correlations; recognizing the identity of the higher beds, however, and thus tying them to the Kansas section.

F. C. Greene[11] recognized the delta-and-basin character of the Oklahoma redbeds and made correlations with Kansas and Texas, and more recently Darsie A. Green[12] has depicted in Oklahoma the wedging-out of thick important sandstones toward the Kansas line.

A conference on the Permian of Kansas and Oklahoma, held on May 8, 1937, at Norman, Oklahoma, by Sigma Gamma Epsilon and the Oklahoma Geological Survey, clarified some questionable points through the papers presented: one by Darsie A. Green[13] with a valuable discussion from Noel Evans; one by Otto E. Brown[14] with discussion from Henry Schweer and Hastings Moore; one by the writer;[15] and through the discussions of many others.[16]

[6] F. W. Cragin, "Observations on the Cimmarron Series," *Amer. Geologist*, Vol. 19 (1897), pp. 351–63.

[7] C. S. Prosser, "The Upper Permian and Lower Cretaceous," *Kansas Geol. Survey*, Vol. 2 (1897), pp. 51–194.

[8] C. N. Gould, "Notes on the Fossils from the Kansas-Oklahoma Red-Beds," *Jour. Geol.*, Vol. 9 (1901), pp. 337–40.

[9] C. N. Gould, "Geology and Water Resources of Oklahoma," *U. S. Geol. Survey Water-Supply and Irrigation Paper 148* (1905), pp. 52–77.

[10] F. L. Aurin, H. G. Officer, C. N. Gould, "The Subdivision of the Enid Formation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 8 (August, 1926), pp. 786–99.

[11] F. C. Greene, "A Summary of the Stratigraphy and Problems of the Permian of Oklahoma," *Stratigraphic Society of Tulsa*, abstract (January, 1932).

[12] Darsie A. Green, "Permian and Pennsylvanian Sediments Exposed in Central and West-Central Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 11 (November, 1936), p. 1456.

[13] Darsie A. Green, "Major Divisions of Permian in Oklahoma and Southern Kansas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 12 (December, 1937), pp. 1515–33.

[14] Otto E. Brown, "Unconformity at Base of Whitehorse Formation, Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 12 (December, 1937), pp. 1534–56.

[15] Geo. H. Norton, "Lower Red-Beds of Kansas," abstract, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 12 (December, 1937), pp. 1557–58.

[16] Robert H. Dott, editor, "Discussions at Permian Conference, Norman, Oklahoma, May 8, 1937," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 12 (December, 1937), pp. 1559–72.

STRATIGRAPHY

Cragin's amended classification of the red-colored strata above the gray Wellington shales is compared with the classification used in this paper.

Cragin's Classification			*This Paper*	
		CIMARRON SERIES		
Divisions	*Formations*	*Members*	*Formations*	*Members*
	Big Basin sandstone		Big Basin	
	*Hackberry shale			
KIGER	Day Creek dolomite		Day Creek dolomite	
	*Red Bluff beds		Whitehorse	Rush Springs sandstone Relay Creek dolomite Marlow sandstone
	Dog Creek shale		Dog Creek shale	
	Cave Creek	Shimer gypsum Jenkins clay Medicine Lodge gypsum	†Blaine	Haskew gypsum Shimer gypsum Nescatunga gypsum Medicine Lodge gypsum
SALT FORK	Flower-pot shales		Flower-pot shales	
	Cedar Hills sandstones		Cedar Hills sandstone	
	Salt Plain measures		Salt Plain	
	Harper sandstones		Harper sandstone (restricted) Stone Corral dolomite (anhydrite) Ninnescah shale	Kingman sandstone Chikaskia sandstone
		BIG BLUE SERIES		
	Wellington shales		Wellington	

* Name pre-occupied—dropped.
† Wider usage—not priority.

WELLINGTON FORMATION

Before discussing the redbeds, it is necessary to comment on the Wellington shales, on which the Cimarron rests.

Raymond C. Moore[17] and N. W. Bass[18] include more section under the name Wellington than did Cragin who named it, having included the salt-bearing Geuda measures of Cragin, and the underlying gypsum- and anhydrite-bearing shales and thin calcareous mud-stones, down to the Hollenberg and Herington limestones, respectively.

[17] R. C. Moore, "Oil and Gas Resources of Kansas," *State Geol. Survey of Kansas Bull. 6* (1920), p. 63.

[18] N. W. Bass, "The Geology of Cowley County, Kansas," *State Geol. Survey of Kansas Bull. 12* (1929), p. 99.

Since the early writings of Hay,[19] Haworth,[20] and Kirk,[21] Dunbar[22] reported on the insect remains of the Carlton limestone, a stratum belonging in the salt- or anhydrite- and gypsum-bearing section, Romer[23] and Elias[24] tentatively placed the base of the Permian (Artinskian) at this horizon in the Wellington formation based on the vertebrate evidence, Bass[25] outlined the Kansas salt basins, and Ver Wiebe[26] contributed a subdivision of the Wellington in central Kansas.

Because of the soluble nature of the salt, anhydrite, and gypsum contained in the formation, outcrops are poor and disconnected, and despite the careful work already done, information is still incomplete, especially in the middle salt-bearing part of the formation.

A reasonably careful study of the topmost 300 feet of the Wellington shales shows them to be largely gray clay shales with many unimportant, thin, calcareous, mud-stone beds and lentils, some of which have an eggshell or skull-like concretionary nature, considered of "algal" origin. Some of these have distinct enough character to be identified from one drainage to another. In the lower part of the 300-foot section are some red shales, associated with mud-stones bearing casts of salt "hopper-crystals." This redbed and hopper-cast zone may belong to the salt-bearing section of the Wellington formation, which Cragin named "Geuda salt measures," underlying his "Wellington shales," the "Gray beds" of earlier writers.

Several fossil zones occur in the Wellington formation not previously recorded in geological publications. L. A. Crum[27] of Wichita, Kansas, noted vertebrate remains in Wellington strata while doing field work southeast of the city of Wellington at a location now un-

[19] Robert Hay, "Geology of Kansas Salt," *Kansas State Board of Agriculture 7th Bien. Rept.*, Pt. II (1891), pp. 83–96.

[20] Erasmus Haworth, "Geology of Kansas Salt," *Min. Res. of Kansas (1898)*, Kansas Univ. Geol. Survey (1899), p. 89.

[21] M. Z. Kirk, "Geology of Kansas Salt," *Min. Res. of Kansas (1898)*, Kansas Univ. Geol. Survey (1899), Pls. 5 and 6.

[22] C. O. Dunbar, "Kansas Permian Insects," *Amer. Jour. Sci.*, 5th ser., Vol. 7 (1924), pp. 171–209.

[23] A. S. Romer, "Early History of Texas Red-Beds Vertebrates," *Bull. Geol. Soc. Amer.*, Vol. 46 (1935), pp. 1631–45.

[24] M. K. Elias, "Correlation of Upper Carboniferous and Artinskian in Russia with American Late Paleozoic Rocks," *Proc. Geol. Soc. Amer. for 1935* (1936), pp. 370–71.

[25] N. W. Bass, "Structure and Limits of the Kansas Salt Beds," *Kansas Geol. Survey Bull. 11* (1926), pp. 90–95.

[26] Walter A. Ver Wiebe, "The Wellington Formation of Central Kansas," *Bull. Municipal Univ. of Wichita*, Vol. 12, No. 5, Bull. 2 (1937), p. 18.

[27] Personal communication.

known. E. C. Moncrief,[28] also of Wichita, Kansas, several years ago mentioned the presence of a limestone bed, approximately 125 feet above the Herington limestone, which contained a pelecypod fauna at its outcrop on a hunting-club property near Oxford, Kansas. This is probably the same bed which crops out so prominently at the top of the hill at the sanitarium at the east edge of Geuda Springs, Kansas, which bed has been named the "Sanitarium limestone" by Ver Wiebe,[29] and in which the writer has found pelecypods.

Estheria has also been found at several horizons in the Wellington, the first in a prominent limestone about 100 feet below the top and the second in the top bed of the Wellington. Glen Gordon,[30] a member of the United States Geological Survey, has also found this fossil in much lower beds cropping out at the center of the north line of the NW. ¼ of Sec. 15, T. 24 S., R. 1 E., in eastern Sedgwick County. *Estheria* has also been found in cores obtained in core-drilling this formation but at depths unknown to the writer.

Milan limestone member.—In following the Wellington gray beds up the section from the type locality at Wellington, Kansas, toward the west and north along the best exposures, the break between the gray beds below and red beds above is seen to be so clear as to leave no question as to what Cragin considered the contact. This is marked by a one-foot bed of greenish to gray, shaly, platy, dense limestone, strong enough to afford good outcrops, which are expressed in scarps and benches, with local development of dip-slopes, and characterized, particularly at the outcrop, by an abundance of green copper carbonate, observable in almost any hand sample freshly broken from the ledge. This bed is here named the Milan limestone member for its typical exposure near the southeast corner of Sec. 30, T. 32 S., R. 3 W., 2 miles south of the town of Milan, and along the south bank of the Chikaskia River, in Sumner County. For the purpose of establishing a definite geologic horizon on which to base a study of the overlying redbeds, none is so useful as this bed. This corresponds with Cragin's observations for he says:[31] "As one travels westward from Wellington, the red shales and sandstones of the Harper outcrop are first met with near Milan." Another excellent exposure of the contact is in the SW. ¼, SW. ¼ of Sec. 9, T. 28 S., R. 3 W. Chalcopyrite is the original copper mineral in the unweathered Milan limestone.

[28] Personal communication.

[29] Walter A. Ver Wiebe, *op. cit.*, p. 14.

[30] Personal communication.

[31] F. W. Cragin, *op. cit.*, p. 19.

Three calcareous beds occur in the top 8 feet of the Wellington, with the upper one ordinarily the most prominent as well as the most cupriferous. However, locally there is thinning and weakening of the topmost bed, together with corresponding strengthening and thickening of one of the lower beds, the 3-foot bed or the 8-foot bed below, with increase of the copper content of these beds also. For this reason the name "Milan limestone member" is intended to include all three thin limestones. Locally they are oölitic or mud-cracked and *Estheria* occurs sparingly in the shaly top of the highest bed. A thin bed of maroon shale commonly underlies the topmost bed, separated by a foot of gray shale, the color being readily identified as typical of the Wellington rather than the brick-red of the overlying Cimarron redbeds.

Subsurface.—In the subsurface, the Wellington normally consists of an upper gray shale member, a middle rock-salt member (Geuda), and a lower anhydrite member, with a few thin dolomitic beds in the lower part. The salt extends south into Oklahoma and north into Nebraska but thins out westward as is shown in the cross sections, as a wedge in the shales. The anhydrite beneath has a wider extent, but also pinches out into the shales as the margins of the basin are reached, and eventually the main body of the shale, the combined top and relicts of the bottom, lose their particular identity, and merge with the continental shore-line sediments.

WELLINGTON—BASAL REDBEDS CONTACT

The lowermost redbeds are well exposed in Kansas in the drainages of four rivers: the Smoky Hill, the Arkansas, the Ninnescah, and the Chikaskia. Cragin's Harper sandstones have their sandiest development within 10 miles of the southern boundary of the state; elsewhere sandstones are scarce in the lower parts of the formation, a fact not unknown to Cragin for he says:[32]

> The word sandstones, as applied to this formation, is intended to imply, not that its rocks consist mainly of sandstone throughout their thickness, but that the frequent low ledges of rock which accentuate the formation, are of sandstone.

In Kansas, at least, no unconformity breaks the sequence from the Milan limestone member of the Wellington shales up into the redbeds. Baker[33] says:

> The San Angelo formation-Duncan sandstone which is separated by an ero-

[32] F. W. Cragin, *op. cit.*, p. 18.

[33] C. L. Baker, "Depositional History of the Red-Beds and Saline Residues of the Texas Permian," *Univ. of Texas Bull. 2901* (January, 1929), p. 19.

sional unconformity from the underlying Clear Fork, has been traced from south of the Colorado river in Tom Green County, Texas, northward to Kansas. The writer has found an unconformity between Wellington and Cimarron in Sumner County, southern Kansas. This unconformity, which agrees with the available faunal evidence, is taken as the dividing line between the lower and the higher Permian.

In response to a request for the location mentioned, he writes,[34]

I know I found the conglomerate on a paved highway and I think it was east of the town of Wellington. It was in a road cut on the east slope of a long grade in an open treeless prairie. I judge that it was not far from the locality where I found tufa domes of the Nevada lake type, "fossil" caliche, and fossil brine shrimp (*Estheria*). I think most of the formation there was green-gray or blue-gray clay. The unconformity is marked by a conglomerate, at that time well exposed in the cut at the side of the road. I recall tracing it for a considerable distance.

The only locality known to the writer fitting this description is 5 miles east of Wellington where Avon Creek crosses the Wellington-Oxford highway. Here is a road cut on the east slope of a long grade in an open treeless prairie. It is not far from "algal" beds which call to mind the tufa domes of prehistoric Lake Lahontan. *Estheria* could be expected, but has not been found by the writer at this locality. Visible from the road and about 100 feet north of it in a bank above a creek bed is a prominent exposure of conglomerate resting unconformably on eroded Wellington shales. The conglomerate is made up almost entirely of broken blocks of Wellington shales and claystones, well cemented together. Soil and sod, but no redbeds, overlie the conglomerate. The Wellington shales *in situ* belong 250 feet below the top of the formation. This conglomerate may be traced for some distance. A mile or so south it lies still lower stratigraphically on the mid-Wellington red shales which are associated with the Geuda salt strata, so it is truly unconformable, but the writer prefers to correlate it with the Abilene conglomerate of Tertiary[35] age which is found at many places above the upper and mid-Wellington beds. Obviously this is not at the contact of the Wellington and the basal redbeds and has no significance in this regard.

On observing the cross-bedded sandstones and conglomerates of the Garber above beds of Wellington in Oklahoma and finding similar coarse clastics above still higher Wellington strata and lower Ninnescah redbeds nearer Kansas, the casual observer seems justified in pronouncing this an unconformity with concomitant cutting-out of

[34] Personal communication.

[35] R. C. Moore, footnote in *Kansas Geol. Survey Bull. No. 6*, Pt. 2 (1920), p. 63. "So-called Abilene conglomerate is Tertiary."

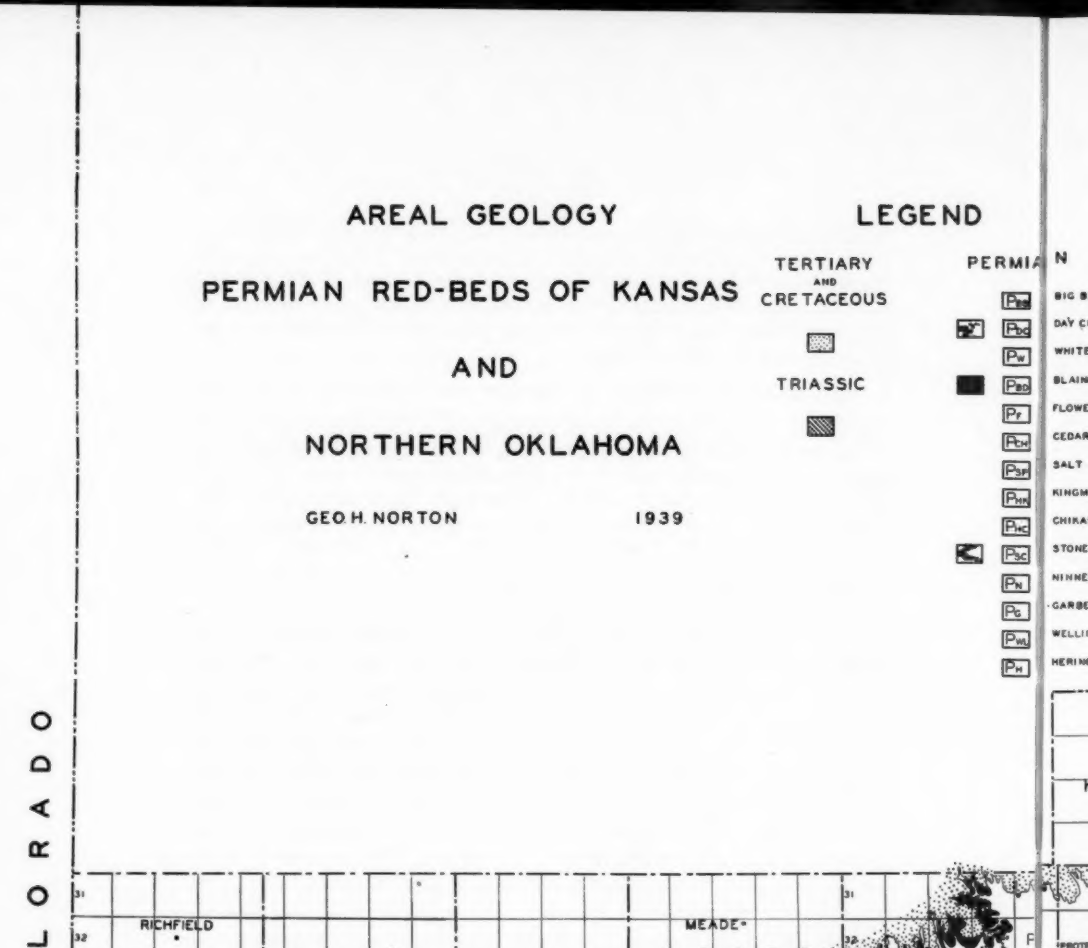
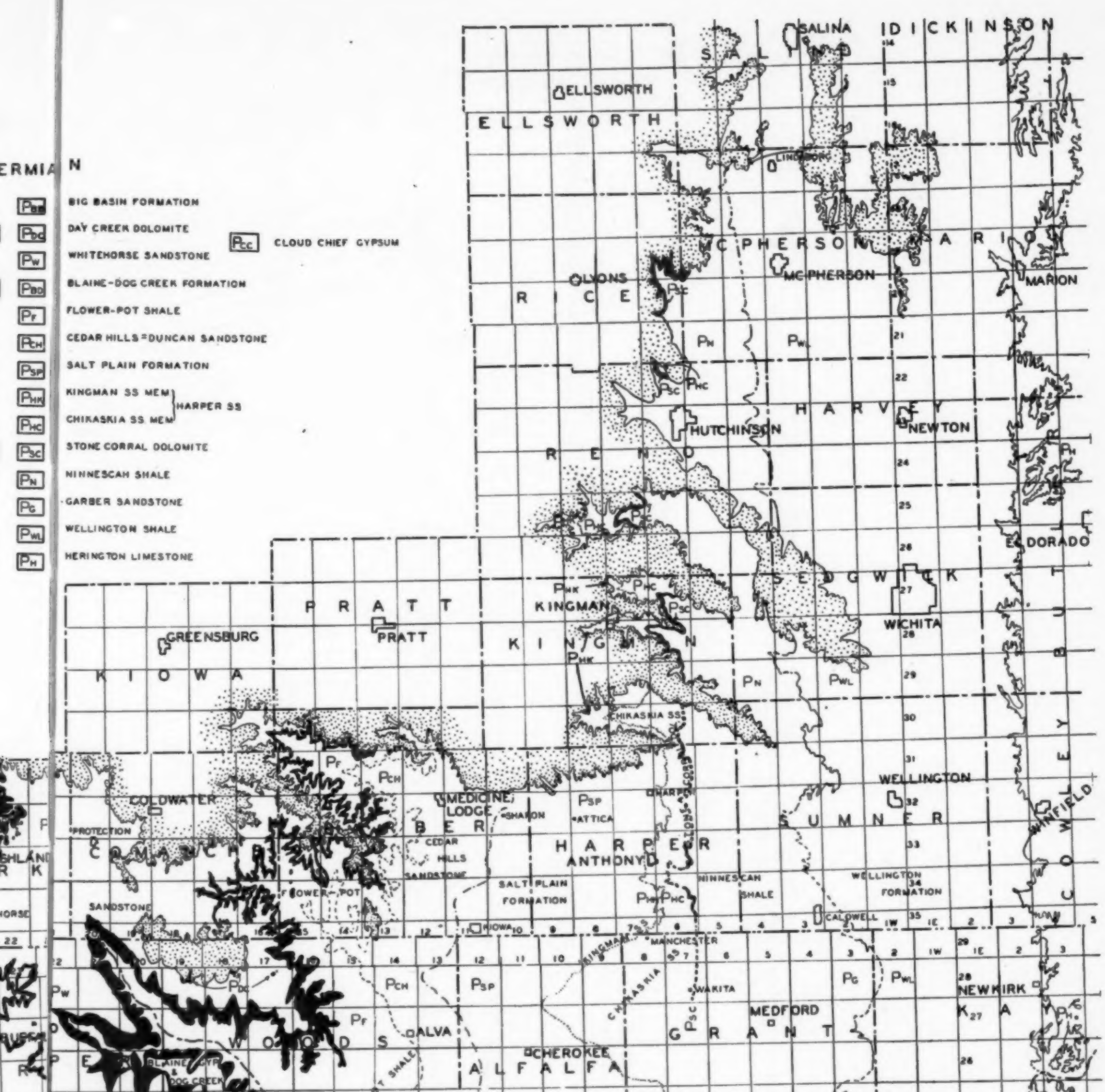


FIG. 1.—Areal geologic map of southern Kansas and northern Oklah



orthern Oklahoma showing distribution of subdivisions of redbeds.

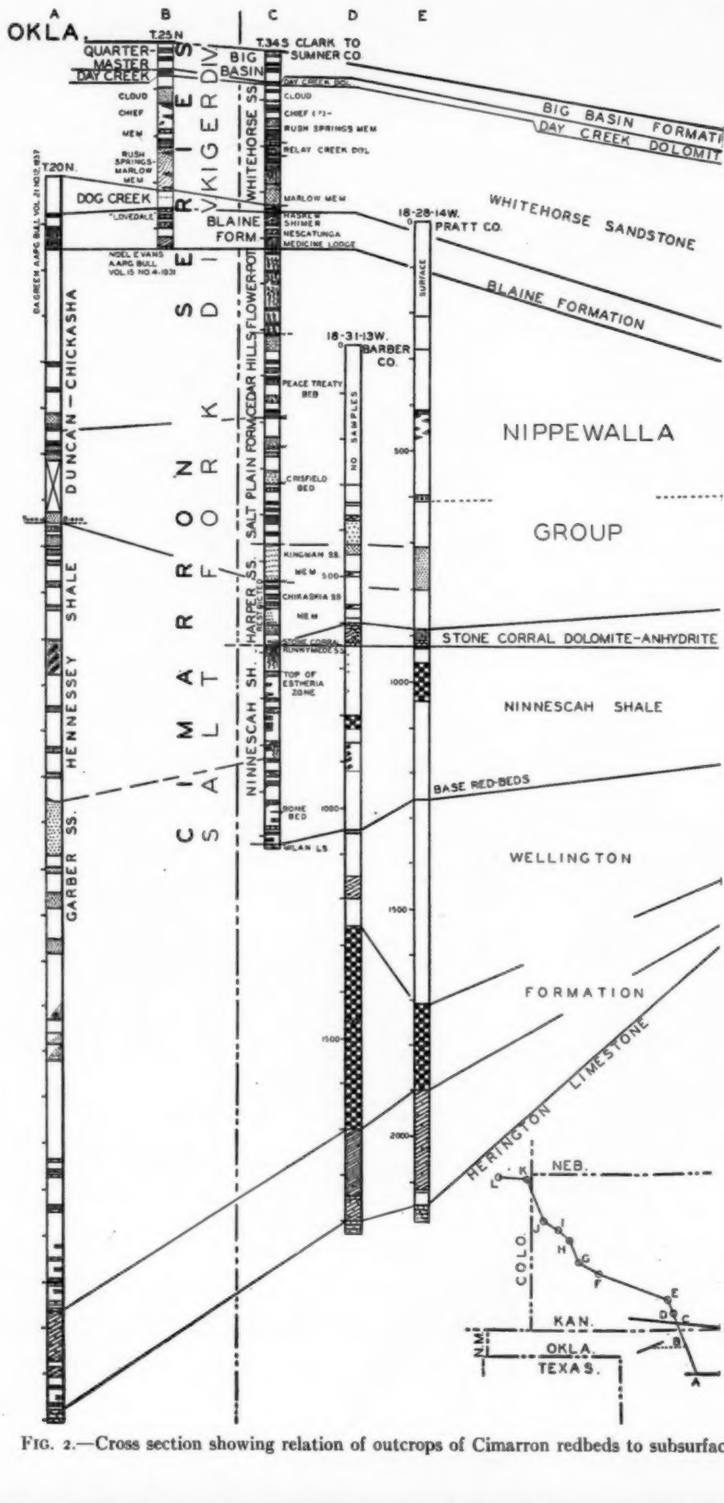
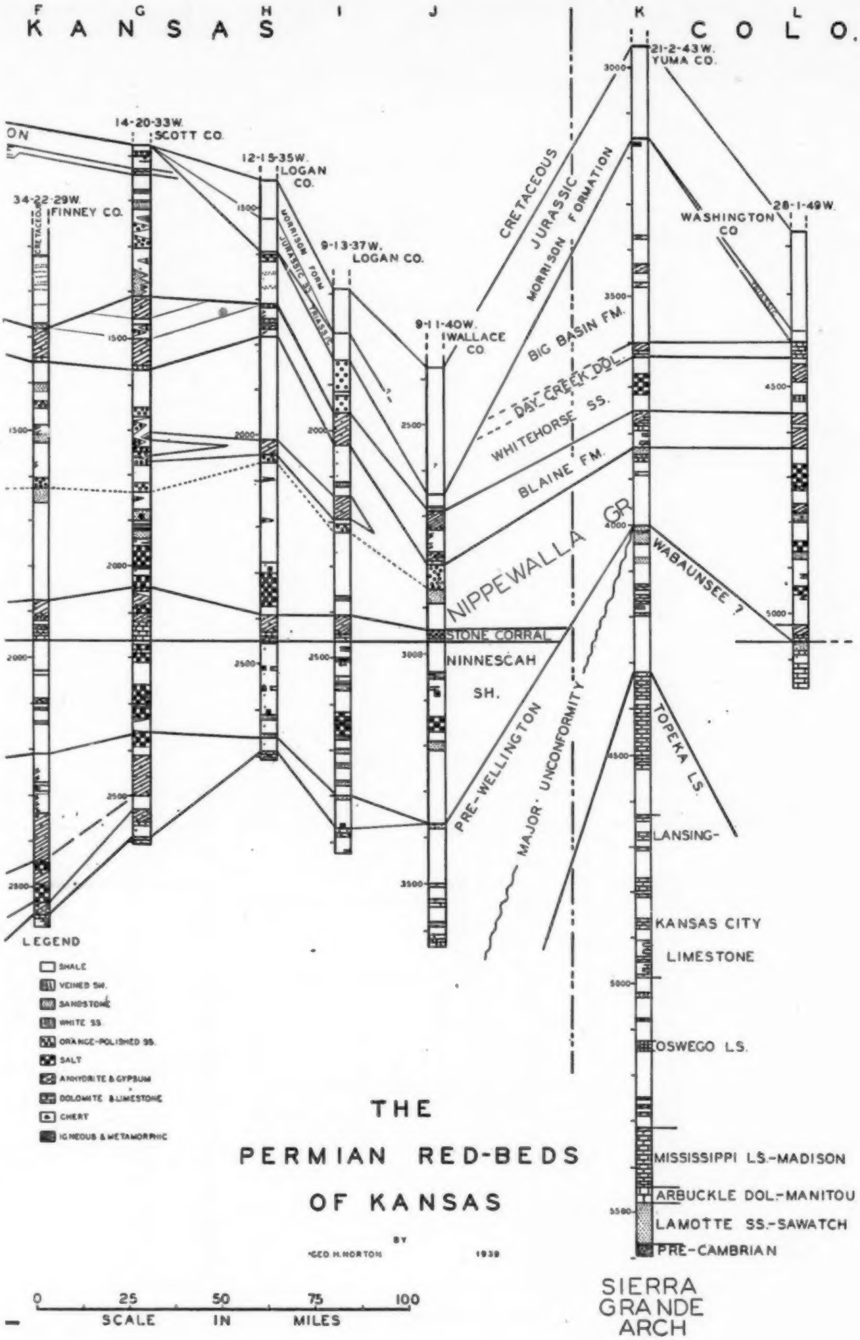


FIG. 2.—Cross section showing relation of outcrops of Cimarron redbeds to subsurface, from



south-central Kansas and adjacent parts of Oklahoma, northwestward into eastern Colorado.

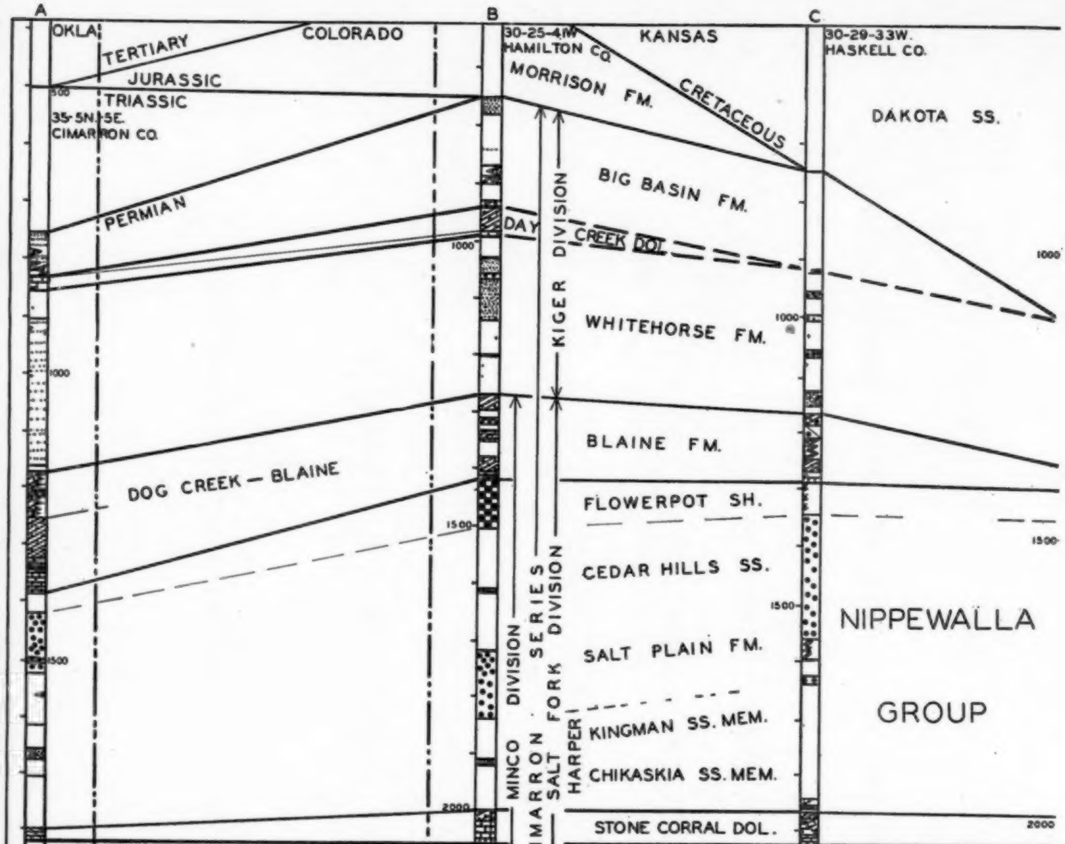
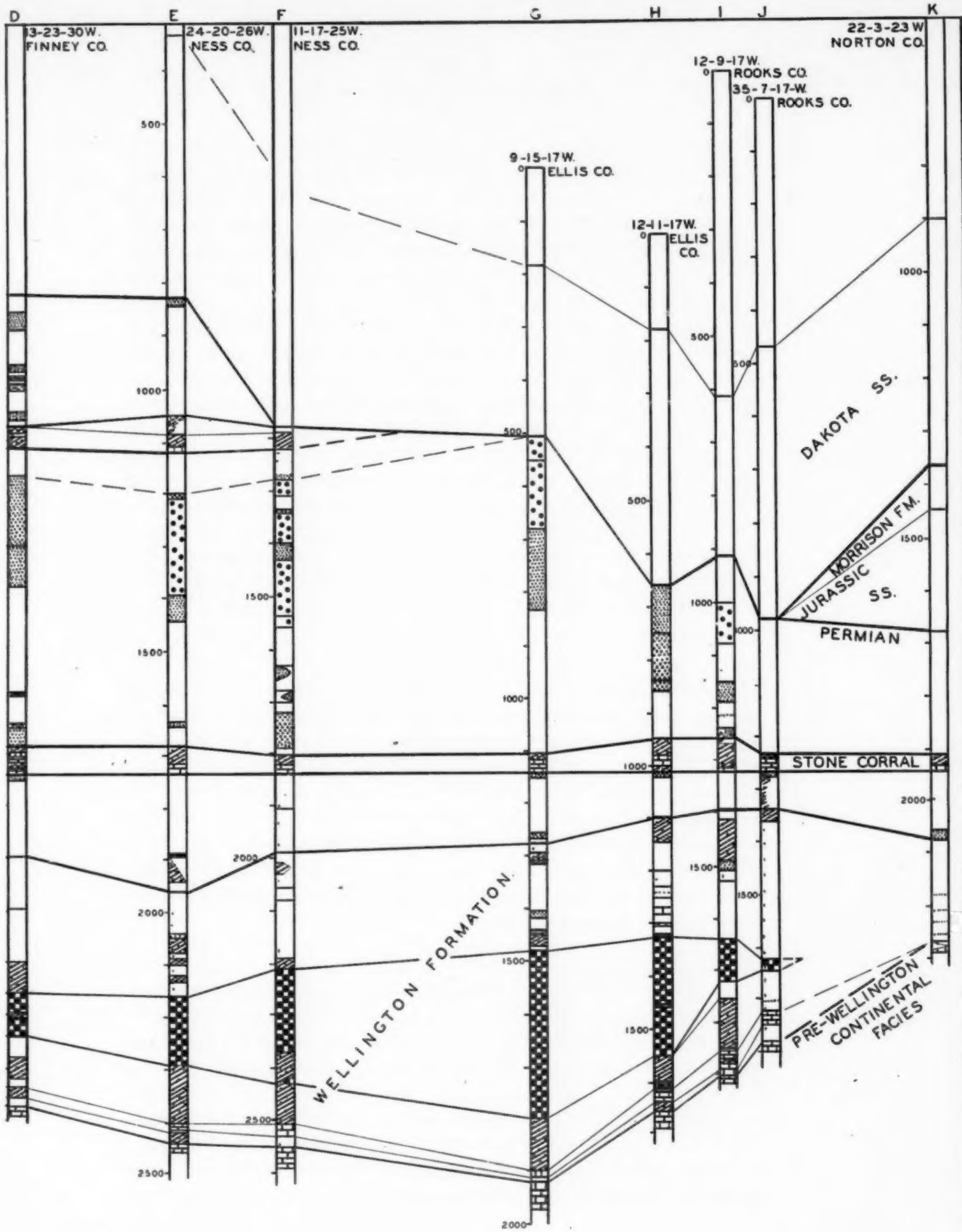


FIG. 3.—Cross section of Cimarron redbeds and adjacent formations in subsurface,



N RED-BEDS OF KANSAS

GEO H NORTON 1939

from Oklahoma Panhandle across Kansas to crest of Central Kansas uplift.

Wellington beds. In tracing the beds of the Ninnescah and Wellington south, however, in detailed fashion, the true picture of changing lithology of individual beds may be noted within the confines of normal super- and subjacent strata. Such lithologic change ordinarily takes place within a very short distance so that where the transitional zone is covered, the correlation of the adjoining areas is puzzling and often misinterpreted as disconformity.

Color changes.—It is well to note that while the color-change line may transgress the section in Oklahoma, the gray beds below the top of the Wellington becoming red southward below the Kansas line, no similar change, except as previously noted, persists above the top of the Wellington; that is, the redbeds of the lower Ninnescah do not turn gray to any great extent northward, and the Cimarron-red and Wellington-gray colors still serve to characterize these formations wherever exposed in Kansas, and in general this characteristic of color may be followed in subsurface examination of cores and drill-cuttings. Even where redbeds become more prominent in the Wellington in and close to Oklahoma, their more maroon-red color is ordinarily distinguishable from the more brick-red shades of the overlying Ninnescah.

Cimarron Series

Succeeding the Milan limestone, the top member of the Wellington formation, without a break, are the red shales and sandstones and higher evaporite beds of Kansas which constitute the Cimarron series, which includes all succeeding Permian redbeds of the state, earlier divided by Cragin into the Salt Fork and Kiger divisions.

Figure 1 shows the areal distribution of the Cimarron beds in southern Kansas and northern Oklahoma. The detailed stratigrapby of their exposures and their relations to adjacent outcrops in Oklahoma, and to the Kansas and Colorado subsurface, are shown in the cross sections (Figs. 2 and 3).

Salt Fork Division

Cragin included in the Salt Fork division the following formations, cropping out within the drainage basin of the Salt Fork of the Arkansas River: Harper sandstones, Salt Plain measures, Cedar Hills sandstones, Flower-pot shale, Cave Creek gypsums (Blaine), and Dog Creek shale.

Because an important anhydrite-dolomite series has been found within Cragin's Harper sandstones, the lowest unit of the Cimarron series, the writer in an earlier abstract of this paper subdivided it into four members named for their type exposures in Kansas, in ascending

order: Ninnescah shale member, Stone Corral member (an evaporite deposit), Chikaskia sandstone member, and Kingman sandstone member.

Restriction of "Harper sandstone."—Later study of this part of the section, and more especially the subsurface, shows the two lower units to merit formation rank, the Stone Corral having an importance comparable with the Blaine and the Ninnescah shale being fully as distinct as the Flower-pot shale, and probably more important a formation. Consequently, the writer would restrict the name Harper to the beds above the Stone Corral, or, where this is absent or unrecognizable, to the beds above the Ninnescah shale, and below the top of the Kingman sandstone. The restricted Harper sandstone would then be primarily a sandstone formation throughout, as typically exposed at Harper, Kansas, the type locality, consisting of two members, the Chikaskia and Kingman sandstones.

NINNESCAH SHALE

The basal formation of the Cimarron redbeds is predominantly a shale unit throughout most of its occurrence in Kansas, and, because of its excellent exposures on both forks of the Ninnescah River in south-central Reno and north-central Kingman counties, is here named the Ninnescah shale. Figure 4 shows the pronounced northward thinning of the formation and the correlation of its seven principal scarp-forming beds. At the outcrop, it is 425 feet thick near the Oklahoma line, thinning to 280 feet 50 miles farther north. Though composed largely of red shales, this formation has a minor amount of gray shale beds and thin, impure, limestone beds, and beds of calcareous sandstone and sand, which maintain their lithologic character in a wide area and have been found useful in mapping the structure of south-central Kansas. The more important of these scarp-forming beds are here numbered and described, the intervals applying chiefly to the area drained by the Ninnescah River.

Bed No. 1.—Bed No. 1 is dense, platy, dove-gray limestone, hardly one foot in thickness, locally nubbly in appearance and characterized by breaking into small rectangular blocks, partly stained with copper carbonate, similar to the Milan limestone member of the Wellington, which it resembles somewhat, though containing less of the copper mineral. In places it forms dip-slopes 30–35 feet above the Milan limestone. Ordinarily, it is heavily mud-cracked, leached, pocked, pitted, and locally oölitic. Invariably this ledge is bedded between two sheets of green shale each about ½ foot in thickness which are considered part of the unit, as is also, for convenience, the calcareous

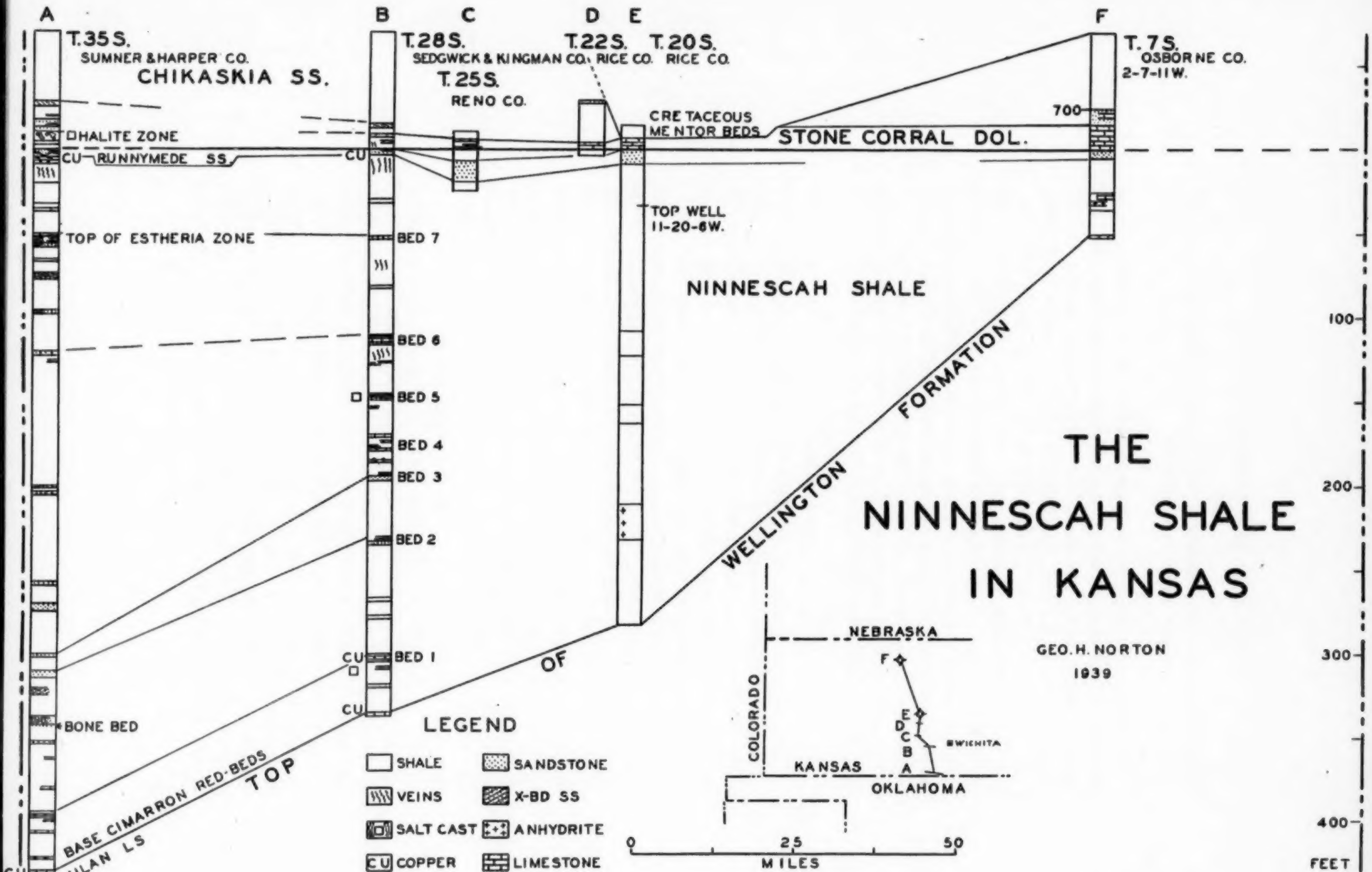


FIG. 4.—Cross section showing subdivision of Ninnescah shale at outcrop, and thinning of formation northward across Kansas.

bed one foot thick approximately 5 feet below it, of a more erratic nature, which is in some places red, less calcareous, and commonly veined with aragonite.

The shales intervening between the Milan limestone and Bed No. 1 are well exposed in the SW. $\frac{1}{4}$, SW. $\frac{1}{4}$ of Sec. 9, T. 28 S., R. 3 W., as well as at the type locality of the Milan limestone, where limestone Bed No. 1 forms the higher bench, with the Milan limestone close above the river level. Near the Oklahoma line, a one-foot bed of clay pebble conglomerate, about 10 feet above the base, forms a minor benchlet.

Like the Milan limestone, limestone Bed No. 1 contains fossils of the "brine shrimp" *Estheria*, and salt casts have been found in the lower stratum.

Although many of the limestones of the Ninnescah member grade into sandstones toward the Oklahoma boundary, this is not the case with Bed No. 1 which maintains its limestone character intact for 40 miles, extending across the state line.

Bed No. 2.—Bed No. 2—a sandstone—is the next highest prominent scarp-forming bed above the Bed No. 1 limestone, and lies about 100 feet above the top of the Wellington. Although its thickness varies from 1 to 5 feet, it is traceable for 60 miles and consists of a ripple-marked double bed of gray, calcareous sandstone with 2 feet of red shales between the individual scarp-forming units of sandstone. It is excellently exposed through Grand River township (T. 27 S., R. 4 W.), between Cheney and Ost (St. Joe). The bed is highly fossiliferous, containing great numbers of *Estheria* shell impressions, even after losing its calcareous nature near the Oklahoma line where it increases in thickness and becomes cross-bedded.

The underlying red shales become more sandy southward, and several miles from the Oklahoma line certain zones "go Garber," that is, take on abruptly the extremely cross-bedded and conglomeratic character, with accompanying local unconformity, so typical of the Oklahoma "Garber," a deltaic phase of the lower Ninnescah.

Slightly lower than midway of these shales, there is a thin, calcareous, fissile, ripple-marked sandstone, which in places makes a mild bench. Immediately above this bed, in the excellent exposure east of the highway just south of Caldwell, on Bluff Creek, an inch-thin vertebrate horizon exists from which two teeth, some vertebrae, and other fragments of bony material were taken by the writer. Figure 5 shows a characteristic view of the lower Ninnescah at this vertebrate location.

Bed No. 3.—Bed No. 3 is well exposed on Sand Creek about a

FIG. 4.—Cross section showing subdivision of Ninnescah shale at outcrop, and thinning of formation northward across Kansas.

mile north of the village of Anness, Sedgwick County. The interval separating it from the Bed No. 2 thins from 40 feet at the north in Reno County, to 10 feet near the Oklahoma line. It is sandy limestone, somewhat thicker than the average limestone of the Ninnescah, being 1–2 feet thick, and in consequence has frequently been quarried along the outcrop as foundation stone for farm buildings. At the north it also is a double bed, having a thin bed of similar sandy limestone or calcareous sandstone immediately above it separated by thin red

FIG. 5.—Characteristic view of lower Ninnescah shale at prominent bluff southeast of Caldwell, Kansas, showing calcareous benches in foreground, location of vertebra locality at arrow, and *Estheria*-bearing sandstones at rim-rock in background.

shale. The most striking characteristic of this bed is its ripple-marked upper surface, being pocked as with worm borings. No fossils have been noted in its 60 miles of outcrop, but *Estheria* has been found a few feet above, and a closer search might reveal some in this bed.

Toward the south, this limestone changes very little except to become more sandy, but the underlying shales "go Garber" on approach to the Oklahoma line, with the inclusion of the typical deltaic cross-bedded sandstones and conglomerates.

Bed No. 4.—Fifteen to twenty feet of red and gray shales, and a thin geodal middle limestone, intervene between Bed No. 3 and Bed No. 4, one of the most interesting of the mappable beds in the Ninnes-

cah shale, being a triple bed of thin, dense, gray limestone and intercalated shale partings, largely green and calcareous, but with a red parting above the lowest limestone, totaling 5 feet in thickness. It is characterized for 25 miles or more by "algal" rosette-shaped calcareous inclusions appearing in relief on the weathered surfaces of the outcrop. The bed is typically developed in Ts. 25 and 26 S., Rs. 4 and 5 W., in Reno County, south and southeast of Haven, Kansas, where on the high Tertiary divide south of the Arkansas River, short tributaries cut sharply into raw redbed channels of the Ninnescah drainage, and have carved prominent scarps and gaping re-entrants, toothed with the thin hard limestones here described, with their related strata, in the region known as the "Red Jaw country."

Bed No. 5.—About 30 feet above the distinctive rosette-bearing strata of Bed No. 4, is Bed No. 5, an easily identifiable marker, locally making a weak bench. This thin-bedded, rather fissile, gray, sandy limestone is both ripple-marked and mud-cracked at the top of the main stratum, one foot thick, and bears casts of *Estheria* and small rock-salt cubes. One foot above it, and only half as thick, is a nodular limestone-and-shale stratum which weathers to a layer of calcareous "hard-heads." Locally the sandy fissile fossiliferous bed thickens to several feet. Eight feet below is a peculiar black, crystalline, dolomitic, geodal limestone, which may well be included with this bed, characteristically exposed near Four-Way filling station, 11 miles south of Hutchinson on Highway 17, and west of Haven. It crops out in and around the village of Castleton also, and some of the best exposures lie southeast and southwest of this village in T. 25 S., R. 6 W.

Bed No. 6.—Half encircling the village of Castleton, is the prominent scarp-forming double-limestone Bed No. 6, with its two units separated by 1–3 feet of red and gray shale, approximately 40 feet above Bed No. 5. Locally the topmost part is shaly and more thin-bedded and ripple-marked. Both contain casts of rock-salt crystals. A thin bed of brick-red sandstone underlies the limestone. Numerous thin green calcareous shale bands, containing calcareous nodular "hard-heads," occur in the red shales separating this from Bed No. 5 while the topmost 5–10 feet of the more maroon shales immediately underlying are commonly criss-crossed with a mesh of calcite veining; when this vein material is dissolved through weathering, the original network remains as green veins in the red shale matrix, the red iron oxide coloring having been reduced along the veins. No fossils have yet been noted in this bed. Toward the south it grades into prominent thick green calcareous shale divided by thin red shale parting.

Bed No. 7.—Sunrise school, in the SE. ¼, NE. ¼ of Sec. 2, T. 28 S., R. 6 W., Kingman County, is built on the outcrop at the best exposure of Bed No. 7, the beds having a 3-foot fault only ½ mile south and a few hundred feet east of the section corner. This prominent, gray, calcareous sandstone, 1–2 feet thick, occurs 60 feet above Bed No. 6. It resembles Bed No. 2 in many respects, including the common occurrence of *Estheria*. The writer has no record of this fossil, which links the Ninnescah to the upper Wellington, having been found stratigraphically higher than this horizon in the Kansas redbeds. The bed may be the same as one having similar characteristics in southern Harper County where, within less than a mile of the Oklahoma line, it becomes radically cross-bedded, being the highest bed of the Ninnescah in Kansas so affected, although it is stratigraphically higher than the top of the Garber of Oklahoma. The underlying beds, however, increase their green and gray calcareous shale content toward the south either by new beds wedging in or by thickening at the expense of the red shales. It is not known definitely that this is lateral gradation, but the available evidence points to this conclusion.

Overlying Bed No. 7 are red shales interbedded with some fairly thick gray beds, shaly about midway of the outcrop trace, but becoming increasingly sandy toward the north, particularly at the top, and at the south containing prominent thin limestone beds not present north of the Bluff Creek drainage, thus reversing the conditions noted in lower beds where limestones grade southward first into gray shales, then into sandstones, then into the conglomeratic Garber. This indicates the post-Garber age of this upper part of the Ninnescah, allowing correlation with part of the Hennessey shale.

Disconformity(?).—Between the blocky, keel shales, colored maroon to brick-red, most characteristic of the Ninnescah, and the Stone Corral dolomite is a variable unit of soft to hard, blue-green sandstone with intercalated beds of maroon shale and local brick-colored sandy shale which commonly contain large casts of salt crystals. Exposures of these once salt-bearing strata differ in relation to the underlying beds sufficiently to suggest a possible disconformity, although close examination of available outcrops fails to provide positive evidence of erosion. The general appearance of the salt strata indicates a closer relation to the Chikaskia beds above the Stone Corral rather than to the underlying Ninnescah. The 6-foot maroon shale between the base of the Stone Corral dolomite and the top of the Runnymede blue-green sand, however, is quite typical of the Ninnescah.

Consequently, the writer, while desiring to note the lithologic variations at this horizon which suggest disconformity, for the present prefers to regard these as lateral gradation peculiar to the margin of the evaporite basin.

Runnymede sandstone.—The topmost bed of the Ninnescah, at its northernmost outcrop, is blue-green to gray, shaly sandstone (under the microscope, fine quartz sandstone with some green mica) 7–8 feet thick, with intercalated layers of red shale and sandstone. This becomes a prominent bench-former throughout the southern half of its outcrop, as the immediately overlying and stronger Stone Corral dolomite weakens and disappears as a lithologic entity. As this takes place, a 6-foot maroon shale bed comes in to separate the dolomite from the sandstone here 11 feet thick, including a 2-foot red shale parting, and may be considered evidence of local disconformity immediately beneath the Stone Corral dolomite. Locally, and especially at the south, the maroon shales of the underlying Ninnescah are permeated with veins of secondary gypsum and calcite, resembling, but in a lesser degree, the veined beds of the Flower-pot formation, which also underlies a prominent gypsum-dolomite-anhydrite formation and derives its vein material from these precipitates.

Forrest E. Wimbish kindly directed the writer's attention to the excellent exposures of this horizon near Runnymede in Harper County, where these beds are in a gradational facies, the exposures extending up in the Chikaskia sandstones. Here is well shown the red-maroon shales of the top Ninnescah and the sandstone, reddish at the base and gray and calcareous in the upper principal part of the bed, which in the southern area, contains thin flakes of green copper carbonate in its more shaly parts. A little digging in almost any outcrop of this bed in the drainage of Bluff Creek, Chikaskia River, or the South Fork of the Ninnescah River, will reveal the copper mineral which, as at the base of the Ninnescah, appears to accompany a formation break. In the SE. $\frac{1}{4}$, NE. $\frac{1}{4}$ of Sec. 15, T. 25 S., R. 7 W., large hopper crystals of salt replaced by sandstone have been found in the lower part of the bed. In the vicinity of Runnymede (Fig. 6) the largest halite casts yet found were taken from red standstone 4 feet above the copper-bearing bed, the imprint of the hopper crystal being frosted with secondary dolomite rhombs, the casts being 4 inches square. This makes possible a tentative correlation with the rock-salt bed found in wells, underlying the Stone Corral dolomite and anhydrite in Pratt and Barber counties, first noted by Cragin, but erroneously referred by him to the Salt Plain measures. It is here proposed to name these variable, gray, calcareous, algal, cupriferous, and shaly

sandstones the "Runnymede[36] sandstone" so that in central and northern Kansas, where the sand is well developed and recognizable from cores and drill cuttings, one may identify the "Runnymede sand" as the uppermost bed of the Ninnescah shale and may expect to trace the bed southward into Oklahoma as an aid in making a more detailed correlation with beds of the Enid.

Subsurface.—The Ninnescah shale maintains its predominantly shaly characteristics wherever recognized in the Kansas subsurface, the thickness decreasing north and west toward the margins of the basin, being 290 feet thick at the type locality of the next higher formation, the Stone Corral dolomite, 92 miles north of the Oklahoma line, and only 50 feet thick in Sec. 2, T. 7 S., R. 11 W., 43 miles south of Nebraska, the regional thinning northward being best illustrated in the cross sections. The top bed of the formation, the Runnymede sandstone, has been identified in well cuttings from central and northwest Kansas in Pratt, Stafford, Ellis, Rooks, Osborne, Russell, and Ellsworth counties.

DISCONFORMITY

Some evidence of possible disconformity is apparent in the variable presence or absence of the 6-foot wedge of maroon shale, coming in and wedging out above the blue-green Runnymede sandstone to lie at the base of the Stone Corral dolomite in the southern part of the state. For the present at least, this slight disconformity is regarded as local and of no great significance, although core-drilling has shown similar local discordance 40 miles northwest of the outcrop. The possibility of the pronounced thinning of the Ninnescah shale northward being due to increased truncation of the beds in that direction has been considered and the evidence reviewed with that in mind. However, the evidence gave little support to this possibility and it was concluded that basinward thickening of the strata in a normal manner caused the conditions observed.

STONE CORRAL DOLOMITE-ANHYDRITE

Near the middle of Cragin's Harper sandstones is a dolomite-anhydrite formation, generally present in the subsurface of western Kansas and adjoining states, where it is one of the most persistent

[36] *Historical note.*—The town of Runnymede was named for the Runnymede in England (where the English barons forced King John to sign the Magna Charta) by a number of younger sons of the nobility, and others, who came to Kansas to hunt buffalo and settled here in the late 1870's. Many English customs were introduced including that of "afternoon tea" and riding to hounds along the Chikaskia, with the red-rock canyons echoing to their "yoicks" and "Talley-ho."

and easily identified key markers in the redbeds of the Kansas Permian, and is consequently of greatest value in making subsurface correlations either by core-drill prospecting or by the examination of oil-well cuttings.

This formation makes one of the most pronounced seismograph reflections in the entire stratigraphic column of Kansas, and has received intensive study in reflection-seismograph prospecting.

FIG. 6.—Characteristic view of Stone Corral dolomite ledge at type locality, Sec. 11, T. 20 S., R. 6 W., Rice County, Kansas. Quarry shown was opened for road metal and concrete rubble; earlier it has been quarried for building stone.

The outcrop of this formation, described by Cragin,[37] as "the massive ledge of hard, cellular, gray dolomite on the Little Arkansas River at the eastern border of Rice County, west of south from Windom," which he "provisionally referred to the Wellington Formation," is likewise exceedingly prominent in the redbed surface section.

This evaporite formation is here named the Stone Corral dolomite-anhydrite for the excellent and prominent exposures of the remnantal dolomite in and near Sec. 11, T. 20 S., R. 6 W., eastern Rice County,

[37] F. W. Cragin, *op. cit.*, pp. 17–18.

close to the historic Stone Corral fort,[38] where the wagon trains of the pioneers forded the Little Arkansas River on the Sante Fe trail. Figures 6 and 7 depict the massive blocks breaking from the outcrop which furnished, with a minimum of quarrying, the material for the huge stockade. Figure 7 also shows the ripple-marked basal layer, the ripple marks being present in this stratum over a considerable area.

FIG. 7.—Ripple-marked Stone Corral dolomite near type locality, north line of Sec. 22, T. 20 S., R. 6 W., Rice County, Kansas.

[38] "On the west bank of the Little Arkansas river, about 20 miles south-west of McPherson, stands a bronze tablet. It reads: 'Sante Fe Trail Crossing, 1822 to 1872.' It was there that the old trail from Westport, Mo., to Santa Fe, N. M., crossed the Little Arkansas river at a ford. C. E. Lindell, banker at Windom, has dug into the history of the trail and of the . . . crossing. Near the crossing a stone corral was built . . . as protection against the savage Indians that ravaged the Kansas plains. Probably the 'hot spot' on the trail, Lindell explained, so far as menace and attacks by Indians was concerned, was the stretch lying between the Stone Corral ford and Pawnee Rock in what is now western Kansas. It is likely that more blood was spilled along this stretch of the trail than any other part, for here it was that there was the best hunting ground of the Indian tribes and they were more apt to be encountered here.

" . . . The corral, built of huge stone blocks set together without mortar was 300 feet square, nearly as large as a city block. The walls were seven feet high, four feet thick at the base. . . . The only entrance was a 10-foot gate. In the corral wagon trains would be driven . . . safe from attack. 'Buffalo Bill' Mathewson . . . operated a store within the Stone Corral. Col. William F. Cody, later to be known as 'Buffalo Bill,' was a clerk, as a young man, at Mathewson's store. . . . After the Civil War the corral was used as a fortress to protect the whites between the Smoky Hill and Arkansas rivers."—Kenneth F. Sauer in *The Wichita Eagle*, February 13, 1938.

The Stone Corral dolomite and associated anhydrite has at various times been regarded, erroneously, as a member of the Salt Plain formation, of the Flower-pot shale, and as late as 1930[39] has been correlated with the Medicine Lodge gypsum.

With greater accuracy it has been referred to as "Lower Enid Anhydrite" by Daniels[40] and by Taylor,[41] as "Enid Anhydrite" by Lerke,[42] as "Cimarron Anhydrite" generally by Kansas geologists and Brown,[43] while some Oklahoma geologists have used the term "Hennessey Anhydrite."

Credit for first recognizing the correlation of the subsurface "Cimarron Anhydrite" with the outcropping Stone Corral at its type locality and in the adjacent Welch pool, goes to William L. Ainsworth, of Wichita, Kansas, who established this correlation after core-drilling to the dolomite marker in Rice County, and so informed the writer in 1929.

The name "Stone Corral" was first applied to this dolomite by the writer in a preliminary abstract of this paper published in the program of the March 21, 1935, annual meeting of the American Association of Petroleum Geologists, at Wichita, Kansas, where it was read by title, the paper itself being presented before the Kansas Geological Society at Wichita, Kansas, April 17, 1935, and this name has since been used by Koester[44] and Green,[45] using the writer's section. Its areal extent, as traced by the writer, is shown by this name on the geological map of Kansas (1937).

The Stone Corral dolomite has lost its anhydrite and gypsum portions at the outcrop through hydration and solution of percolating ground waters. The remaining cellular dolomite ledge has its maximum development near its north-most exposed limits in T. 20 S., R. 6 W., where the massive 6-foot ledge forms a prominent scarp entirely across the township north and south, and as shown in the illustrations, great slabs break off and creep down the steeper slopes

[39] J. W. Ockerman, "Rocks not Exposed," chapter in "The Geology of Mitchell and Osborne Counties," *Kansas Geol. Survey Bull. 16* (1930), p. 32.

[40] J. I. Daniels, "Data on Deep Wells in Southwestern Kansas and Adjoining States," *Proc. 4th Ann. Field Conference Kansas Geol. Soc.* (1930), p. 139.

[41] Garvin Taylor, "The Hugoton Gas Area in Southwestern Kansas," *Proc. 8th Ann. Field Conference Kansas Geol. Soc.* (1934), p. 59.

[42] Boris V. Lerke, "The Hostetter Test, Kiowa Co., Colorado," *Colorado School of Mines Mag.* (May, 1938), p. 197.

[43] Otto E. Brown, *op. cit.*, p. 1553.

[44] Edward A. Koester, "Geology of Central Kansas Uplift," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 10 (October, 1935), p. 1410.

[45] Darsie A. Green, *op. cit.*, p. 1522.

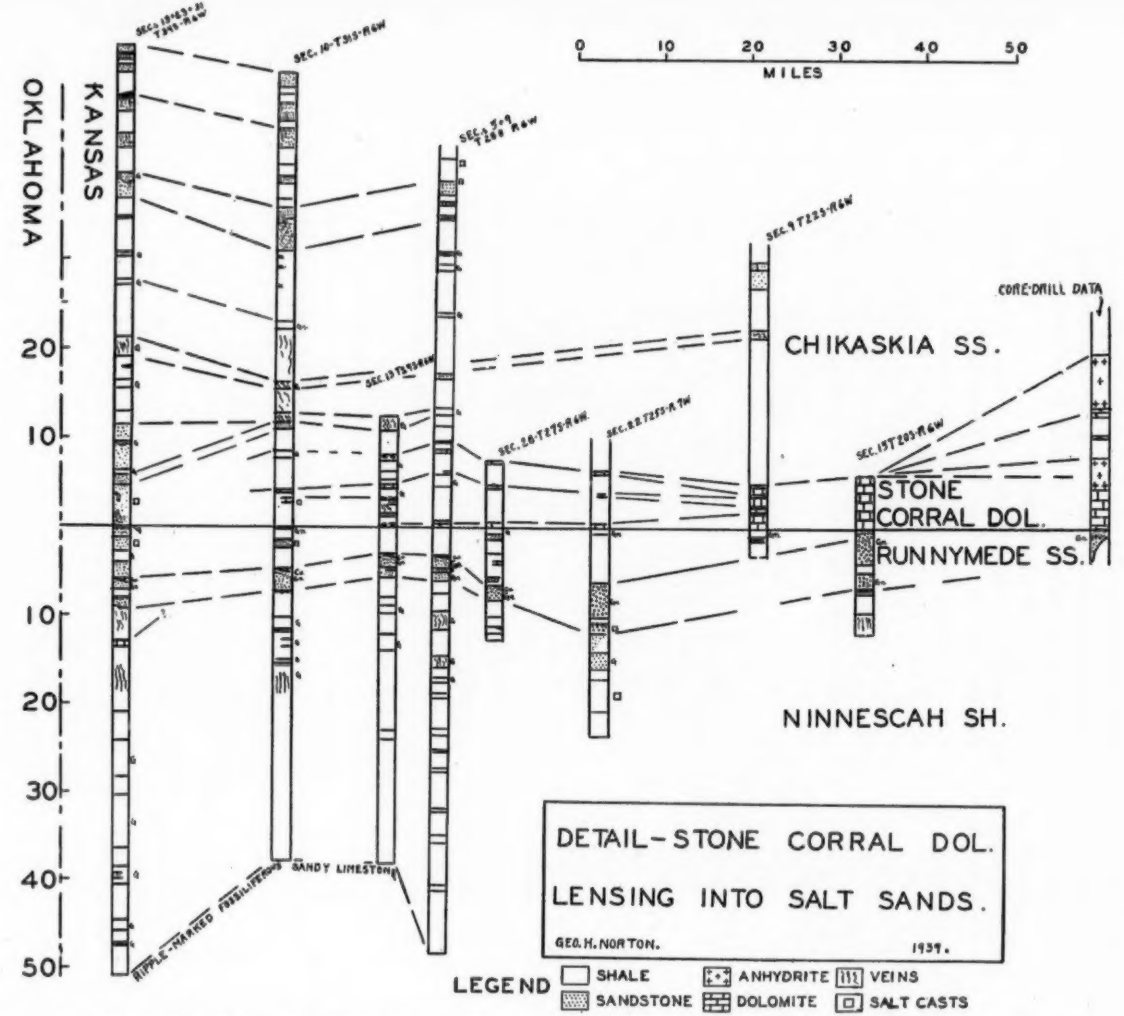


FIG. 8.—Cross section of Stone Corral dolomite across Rice, Reno, Kingman, and Harper counties, where it lenses out into redbeds.

as if the gypsiferous, and perhaps saliferous, soft red siltstones and shales had melted away beneath it. The massive ledge weathers into layers ranging from an inch to a foot in thickness, the rock itself varying from crystalline to dense, and an almost lithographic, texture. The color is ordinarily gray but locally red and pink streaks appear, forecasting the introduction of red shale partings in the dolomite at its next outcrop two townships south, in the drainage of the Arkansas River.

The cellular nature of the massive dolomite is due to the dissolving of anhydrite crystals which once occupied the cavities, as is readily proved in a core of this stratum from under cover and unaltered by ground waters. Many of the pores and vug-holes of the weathered cellular rock refill with secondary calcite. Heavily weathered dolomite in many places presents a salt-and-pepper appearance, apparently due to oxidation of some included mineral. The only fossil from this formation known to the writer is some fragmentary carbonized wood taken from a core in Stafford County.

To the writer, the change taking place in the Stone Corral dolomite as it extends south to lose its identity in the red-beds is one of the most interesting features of the Kansas Cimarron. The massive ledge at its type locality perfectly represents the basal dolomitic portion of the complete dolomite-anhydrite section encountered in the subsurface in the greater part of western Kansas, and the changes which take place in this ledge along the outcrop must be similar to the alteration noted underground where the dolomite portion diminishes or vanishes and even the anhydrite thins to a fraction of its thickness, as the bed is traced south and east. (Fig. 8).

South from the type locality, the Stone Corral next is found in a limited outcrop in T. 22 S., R. 6 W., in Secs. 9 and 10, 15 and 16. Here the rock is the familiar massive ledge, stoutly holding up a bold scarp, but a change has taken place. The pink streaks are definitely narrow red partings, especially in the upper part of the bed, which has thinned to about 4 feet. Already the maroon shale wedge has appeared beneath the base of the bed to separate it from the underlying Runnymede sandstone, with which it is closely related in the subsurface many miles west and northwest. Here also can be seen the beds immediately overlying the Stone Corral, about 25 feet of redbeds separating it from thin-bedded, ripple-marked, sandy limestone, salt-and-pepper colored, and less than one foot thick.

The alluvium-covered valley of the Big Arkansas River buries an important area of the outcrop of the Stone Corral, the next appearance being in T. 25 S., R. 7 W., where the Runnymede sand is char-

acteristically developed, but overlain by the 6-foot maroon shale wedge, and it in turn by a thin green shale and a mere ½ foot of ripple-marked, crystalline dolomite, still resembling more than anything else in the entire section the basal beds of the typical Stone Corral. Five feet of red shales split by a thin calcareous bed separate this lower dolomite from the upper thin-bedded ripple-marked dolomite which in its turn is overlain by 6 or 8 feet of redbeds, somewhat sandy.

FIG. 9.—Runnymede sandstone near type locality in SE. ¼ of Sec. 10, T. 31 S., R. 6 W., Harper County, Kansas. Boy stands on bench of red sandstone which contains large hopper-casts of salt crystals. Gray beds below are Runnymede sandstone with flakes of copper carbonate. Horizon of Stone Corral is no longer recognizable.

Still farther south in T. 28 S., R. 6 W., the thin dolomite of the Stone Corral becomes more sugary and geodal, the underlying Runnymede forming the lower somewhat similar bed above the highly veined red shales of the upper Ninnescah.

Figure 9, Sec. 10, T. 31 S., R. 6 W., illustrates the further gradation of these thin remnantal dolomites into sugary geodal lentils and gray streaks in a salt-bearing sandstone toward the south, numerous rhombs of secondary dolomite still frosting local vugs and joints, thus marking the vestigial trace of this prominent formation as it merges into the clastic beds of the lower Chikaskia sandstone.

Subsurface.—Mention has been made of the weakening of the surficial remnants of the Stone Corral member south toward Oklahoma. In the subsurface, this is also true. Normal thicknesses ranging from 30 to 50 feet of the massive dolomite-anhydrite formation in Pratt, Stafford, and Rice counties, and in general over the Central Kansas uplift, thin to 10 feet or less in Kingman County and the formation is in many places not identifiable in well cuttings as far south as Harper and eastern Barber counties. Southwestward, however, this member has a normal thickness in the Oklahoma Panhandle and the Hugoton gas area, and reaches its maximum development in Kansas in a well in Scott County where it is 100 feet thick. It extends still farther westward into eastern Colorado as shown on the cross section (Fig. 2). It is believed to extend northward into Nebraska, but if the thinning of the Ninnescah continues at the rate shown in Figure 4, the Stone Corral would be expected in contact with beds of Wellington, or lower age, a very few miles north of the Kansas line.

As Taylor[46] has pointed out, the dolomite-anhydrite appears to be an intergrowth, with the upper part of the formation anhydrite, the dolomite increasing with depth, yet core drilling shows it to be divisible, at least locally, into several closely related units of anhydrite with thin shale partings and locally having a very thin dolomite bed at the base of one of the upper members with the principal 1- to 8-foot bed of anhydritic dolomite lying at the base, in most places with several feet of blue-green shaly sandstone, the Runnymede, immediately beneath it and in turn resting on typical Ninnescah redbeds. Normally there are two main gypsum anhydrite beds separated by a few feet of gypsiferous red shale, although locally one or more other beds occur higher above these.

DISCONFORMITY

It has been noted that the member thickens by the addition of new gypsum beds at the top and this fact, together with the fact that samples from some wells contain no vestige of anhydrite or dolomite at this horizon, although offset by other wells containing a normal thickness, as in the Shallow Water pool, Scott County, suggests a certain amount of local disconformity close above this horizon. That the latter occurrence is no local phenomenon is readily proved by the records of core drillers which report similar local erratic disappearances of the anhydrite only, or of both anhydrite and dolomite, in several counties, an anomaly hardly explainable by irregularities of

[46] Garvin Taylor, *op. cit.*, p. 59.

deposition, or removal by solution of a bed normally so uniform in character throughout the region.

Tentatively, therefore, we may postulate on the basis of these facts, at least, a local disconformity marking the upper limits of the evaporite member on which the irregular sands of the succeeding Chikaskia member of the Harper formation were laid down.

Nippewalla Group

Subsurface studies in Kansas (Figs. 2 and 3) show that the several hundred feet of redbed strata between the Stone Corral and Blaine formations are so closely related, except at the surface, that their dividing boundaries are in many places obscure or unrecognizable, thus making a group designation desirable. The writer here proposes the Indian name "Nippewalla" for this group of related formations (the Harper sandstone, as already restricted, the Salt Plain formation, the Cedar Hills sandstone, and the Flower-pot shale), being so designated for the township of Nippewalla (T. 33 S., Rs. 11 and 12 W.), Barber County, Kansas, which embraces many strata of the Flower-pot, Cedar Hills, and Salt Plain formations.

HARPER SANDSTONE

The Harper sandstone as here described has been restricted by the removal of the previously described Ninnescah and Stone Corral formations, which to this time have been included in Cragin's Harper sandstones.

The remaining beds, red sandstones for the most part, are most typical of the Harper as generally known, and are the beds exposed at and near the type locality. The restricted Harper sandstone may then be divided into two members due to their natural differences: the Chikaskia member, below, and the Kingman member, above.

Chikaskia member.—Succeeding the Stone Corral dolomite and perhaps separated from it by local unconformity as previously explained, are the various strata included in the Chikaskia member, named for the Chikaskia River along which drainage excellent outcrops occur. This member, ranging from 100 feet thick in Kingman County to 140 feet in Harper County, where it crops out in a narrow north-south belt, has a three-fold character. 1. At the base, is a highly variable sand and shale section, the soft red sandstones containing grotesque concretions and salt casts, the more resistant red sandstones, several feet thick, weathering at the ordinary exposure to an exfoliated, bulgy or pot-bellied appearance (Fig. 10), each of these ledges being capped by gray, fissile, fine-grained, ripple-marked and

in places cross-bedded sandstone, the lower contact of which is very irregular so that the thickness varies abruptly from 1 or 2 feet to twice that thickness but everywhere levels off at the top. 2. Next is a series of bench-forming, well cemented, even-bedded, hard, red sandstones, weathering to a rough jagged surface, whose beds are locally quarried for dimension stone. These beds, together with those above, far better than those underlying, represent the rock character ordi-

FIG. 10.—Basal part of Chikaskia sandstone at type locality in Sec. 10, T. 31 S., R. 6 W., Harper County, Kansas, showing characteristic bedding.

narily associated with the name "Harper sandstones." 3. The uppermost third of the Chikaskia is more variable in thickness than the beds above or below, and there is also considerable variation in the composition of the strata. There are numerous white sandstones of fair strength which serve to break up the redbed section but the most distinguishing characteristic of this part of the member, outside of its contact with the next higher member of the Harper, is the sugary-dolomite lentils and concretions in the red shales, characteristically polka-dotted with small green spots.

Locally, there seems to be some variation in the thickness of the upper part of the member, but no definite evidence of unconformity at the base of the overlying Kingman sandstone is found. Local

thickening toward the south in the basal beds of the Chikaskia member takes place by the introduction of new sandstone wedges into the red shales as the formation nears Oklahoma.

Removal by solution of pre-existing anhydrite or gypsum beds, and possibly some salt, in the underlying Stone Corral member, has necessarily confused the stratigraphy along the exposed contact so that there is no uniformity of intervals between individuals beds and every section measured exhibits differences suggesting unconformity.

FIG. 11.—Contact of lower part of Kingman sandstone with upper shaly part of Chikaskia sandstone, $\frac{3}{4}$ mile east of Kingman, Kansas, type locality, on Highway 54. White sandstone marker at base of Kingman sandstone is traceable far into Oklahoma.

With the loss of the included anhydrites of the Stone Corral by solution at the outcrop, the gypsum residue and shale partings which were originally a part of the Stone Corral are, for convenience, included in the basal Chikaskia, although it is realized that a condition exists here which is essentially parallel with that of the Blaine-Dog Creek-Whitehorse interval and which, if as well exposed, might yield an equal amount of controversial literature.

No fossils have been noted in the Chikaskia member. At the outcrop its thickness varies from 100 feet at the north to 160 feet near the Kansas-Oklahoma border. Beds exposed at the eastern outskirts

of Wakita, Oklahoma, belong to the lower part of this member of the Harper. Large salt casts of red sand pseudomorphic after halite are found at one locality, in the SW. ¼, SW. ¼ of Sec. 5, T. 28 S., R. 6 W., Kingman County, a short distance above the base.

The Chikaskia member of the Harper sandstone appears to be equivalent to the upper, Bison banded member of the Hennessey shale of Oklahoma, as exposed at the type locality.

The Chikaskia member can be differentiated in the subsurface when the sugary geodal fragments are plentiful or where the overlying finely micaceous Kingman sandstone can be identified, in which case the member includes all strata from the base of the Kingman sandstone to the top of the Stone Corral.

Kingman sandstone member.—Above the alternating hard and soft sandstones of the Chikaskia lies the topmost member of Cragin's Harper sandstones—an 80-foot thick body of red sandstones, broken partially by thin beds of red shale and white sandstones, which is named the Kingman sandstone member, because of the excellent and striking exposures of this member in and around Kingman, Kansas, and north and south of that county seat throughout Kingman County. U. S. Highway 54 is cut through a jutting ridge of this sandstone about ¾ mile east of Kingman (Fig. 11) where the basal bed and the lower part of the member may be conveniently studied in contact with the underlying Chikaskia member. In this region, another good section is found at the high hills south of Arlington, Kansas, the greater part of the member being exposed.

The member is exposed in its entirety in the hills a short distance northwest of Manchester, Oklahoma, on the Kansas side of the state line. At this point, the member is about 80 feet thick, with the top established arbitrarily at a bed of maroon shale which is taken to mark the base of the Salt Plain measures of Cragin.

The Kingman sandstone has a prominent 3-foot white sandstone bed at the base which grades into the immediately overlying red sandstone. Some geologists have considered this white bed not to be a stratigraphic plane, but caused by reduction of red color by circulating ground water. White beds are ordinarily much more calcareous than redbeds and in northern Oklahoma and throughout its extent of outcrop in Kansas, this is a plane. The individual beds are evenly stratified and broken with thin red or maroon shales and a few thin white sandstone ledges. Many of the beds are thick and massive and weather readily into a deep canyon topography along the line of outcrop. No fossils have been found in this upper member of the Harper sandstones. Some halite casts occur, but sparingly, some 15–20 feet

above the base. This is the sandstone unit immediately overlying the Hennessey shale and has been generally miscorrelated in northern Oklahoma with the lowermost Duncan sandstone.

A few wells some distance from the outcrops of the Kingman sandstone show this member in its normal thickness as a bed of rather fine-grained, partly micaceous, sandstone. Toward the north and west, however, it is ordinarily indistinguishable from the other adjacent red siltstones. In the early days of cable-tool drilling, it was sometimes possible to recognize this formation by its harder drilling, necessitating the sharpening of the bits.

FIG. 12.—Typical Salt Plain strata in bluffs a few miles northwest of Attica, Harper County, Kansas. Note finely laminated silts and sands between prominent massive sandstone benches. Beds below rim-rock are prominently ripple-marked.

SALT PLAIN FORMATION

The Salt Plain measures of Cragin, because of their poor exposures, have been the least studied part of the Kansas Cimarron section. It is probable that few geologists other than the writer have seen exposures of this formation in its entirety. At various times, the writer attempted to extend the well exposed Cedar Hills section downward and to build up the section above the Kingman sandstone, but out-

crops were rare, topographic relief very low, and efforts in this direction were often futile. With the delimiting of the possible area of outcrop, a visit to the divide north of Attica resulted in the discovery of exposures which could be measured and furnished this "missing link" of the redbeds of Kansas (Fig. 12).

If we accept, as the writer and many other geologists do, the prominent white sandstone, at the base of the "bright-red sandstones in the low bluff north of Sharon" specifically noted by Cragin, as the base of the Cedar Hills sandstone, then the underlying flaky red siltstones and included sandstone beds to a thickness of 265 feet comprise these little known strata of the Salt Plain formation.

The lower part of the formation contains a few ledges of red sandstone which locally crop out in comparatively strong benches, but the greater part, being flaky, silty shale, has permitted the development of flat featureless plains in which the drainage has cut only channels with low banks but which bring to the surface in a white crust the connate salts of the formation. Cragin referred to this topography as "Salt-plains, salt-marshes, salt draws, salt-bars, salt-licks, salines, etc.," naming this formation for the Great Salt Plain of the Salt Fork near Cherokee, Oklahoma, one of the more noteworthy natural phenomena of this region which has developed, to an extreme, the type of topography characteristic of this formation.

The familiar cliff-and-canyon topography of the Kingman sandstone may be readily recognized in the line of cliffs bounding the south bank of the Salt Fork up and down stream from the eastern limit of the Great Salt Plain. Although Gould[47] states, "The largest salt plain in Oklahoma—the Salt Fork Plain—is located near the middle of the Harper," yet, even though part of the Great Salt Plain may be carved out of the upper part of the Kingman sandstone, no small part of its salt content must have been leached from these beds and the western extent of the plains must be developed on the beds here considered and to which its name is given.

The upper part of the formation as here recognized contains two prominent and important sandstone beds which have received individual names by geologists mapping their outcrops in Barber and Harper counties.

The uppermost bed, about 25 feet thick, lies 42 feet below the base of the Cedar Hills, as here established, and was given the field name "Gerlane" sandstone bed by D. A. Holm without his realizing that

[47] C. N. Gould, "The Oklahoma Salt Plains," *Kan. Acad. Sci. Trans.*, Vol. 17 (1901), p. 182.

this name was pre-occupied, having been used by Knight[48] from the same locality for a Tertiary formation.

Holm also advises that the second bed, 29 feet thick and 115 feet below the base of the Cedar Hills, is called the "Crisfield" sandstone bed by field workers, crediting the writer with this name following his leadership of a one-day field conference for the Kansas Geological Society on July 28, 1925, which made a stop at this locality and discussed this outcrop.

Knight,[49] after mapping Barber County for the Kansas Geological Survey, would include the upper of the two sandstone beds here mentioned, with the Cedar Hills sandstone, and there is merit in his argument, especially should all of these heavy sandstones be included. The sandstones, except for the extremely cross-bedded stratum, resemble greatly the sandstones of the Cedar Hills, as they also resemble greatly the sandstones of the Harper.

The included shaly siltstones and shales, however, do not resemble the more shaly parts of the Cedar Hills sandstone, or any other redbeds of the Cimarron series; therefore the writer prefers to leave the base of the Cedar Hills, not at the base of a variable cross-bedded sandstone which may change in lithology and character within a short distance, but at a very prominent white sandstone which maintains its identity for a great many mappable miles at the base of massive red sandstones.

This base of the Cedar Hills sandstone appears to correlate very nicely with Brown's[50] Piedmont sandstone, also a prominent white sandstone beneath a prominent red sandstone bench-former, close to the base of the Duncan of Oklahoma, in Canadian County. In fact, the massive red sandstones in this vicinity, from Okarche at the top, to Piedmont at the base, and also those exposed near Banner and Yukon, are readily identifiable as Cedar Hills sandstone, differing principally in being more cross-bedded and somewhat more shaly between the massive beds. Essentially the Duncan-Piedmont sandstones are actually Cedar Hills.

That this correlation is not a new one is shown by Freie:[51] "Recent studies by H. L. Griley and others, yet unpublished, would indicate that the Duncan is the equivalent of the Cedar Hills of Kansas rather

[48] G. L. Knight, "The Gerlane Formation," *Proc. Geol. Soc. America for 1933* (1934), p. 91.

[49] G. L. Knight, "Geology of Barber County, Kansas," unpublished manuscript, 1929.

[50] Otto E. Brown, *op. cit.*, p. 1553.

[51] A. J. Freie, "Sedimentation in the Anadarko Basin," *Oklahoma Geol. Survey Bull. No. 48* (January, 1930), p. 15.

than the Harper."—"The Duncan sandstone is believed to be thickest in Stephens, Garvin, and Grady counties, where a total of 180 feet was measured." It is no accident that the Cedar Hills sandstone is also 180 feet thick.

In the past it has been difficult to reconcile the Kansas nomenclature of these Cimarron strata with those of Oklahoma, due to misconceptions and miscorrelations on crossing the state line and the broad alluvium-covered valleys of the Salt Fork and Cimarron rivers. With the proper correlation of Cedar Hills and Duncan sandstones, and with the proper restriction of the Hennessey shale to the base of the Kingman sandstone, it can be recognized that the several hundred feet of redbed strata immediately beneath the true Duncan are, in actuality, Salt Plain and Kingman. On Schweer's cross section, just referred to, his Reeding sandstone is lower Salt Plain or upper Kingman, while his "Anthony sandstone" must be identical with the base of the Kingman sandstone, either name being equally appropriate for this member of the Harper.

Subsurface.—On the cross section (Fig. 2) is suggested the possible correlation of the mid-Salt Plain sandstone bed with the lowest "orange-polished sandstones" of the central and western Kansas subsurface.

CEDAR HILLS SANDSTONE

Above the Salt Plain formation lie 180 feet of red sandstone, named Cedar Hills sandstone by Cragin, including a prominent white sandstone at the base and top, the latter containing "snow-balls" of concretionary white gypsum. Softer, more shaly, red siltstones separate the more massive sandy beds and serve to break the formation into recognizable layers. These soft sandstones are readily carved into canyon topography by the streams, the more resistant beds holding up the hills and ridges and weathering to rounded forms. Two beds in particular are more readily identified than others, save the top and basal beds: the first 127 feet below the top weathers into forms compared with haystacks, and the second, 100 feet below the top, weathers to more smoothly rounded outcrops and benches of lighter-colored appearance which makes possible its correlation over considerable distances. The latter bed has been called the "Peace Treaty" bed, P. W. Anderson[52] naming it for its outcrop in the State Park 2 miles east of Medicine Lodge, which commemorates a peace treaty, signed at a natural amphitheater in these rocks in 1867, whereby the Plains Indians agreed to make no further attacks on

[52] Personal communication.

wagon trains or railroad construction parties. The formation itself is confined to a belt trending northeast and southwest across Barber County and western Harper County. Where the upper beds of the formation are studied, they are often seen as a plateau dissected into bad-lands on which the steep slopes of the Flower-pot shale rise to the Blaine cap-rock, as pictured in Figure 13.

FIG. 13.—View of Cedar Hills sandstone, Flower-pot shale, and Medicine Lodge gypsum, southwest of Medicine Lodge, Barber County, Kansas.

The Cedar Hills sandstone is recognizable far into Oklahoma, being excellently exposed below the Flower-pot beds near Okarche along Highway 81 and also about midway between El Reno and Oklahoma City on Highway 66, where it is mapped and generally recognized as Duncan sandstone, although at the exposures mentioned the lithology is apparently more characteristic of the Cedar Hills than of the Duncan at the type locality.

The correlation of the Cedar Hills sandstone with the Duncan and Piedmont sandstones of Oklahoma, as exposed west of the type locality of the latter, is believed to be the simplest and most logical one. However this concept differs from the interpretation of Green,[53] who pictures the Duncan sandstone of northern Oklahoma as a

[53]Darsie A. Green, *op. cit.* (1937), p. 1522.

sandy facies of the lower Flower-pot shale, which appears to be abnormally thick in the Fairview area. The writer believes that the upper Cedar Hills beds have here become shaly, resembling the true Flower-pot, only to resume their Cedar Hills-like characteristics farther south as the more cross-bedded Duncan. The writer considers that the existing differences with Green's views are largely a matter of the names applied, rather than more fundamental differences of correlation of the strata involved, especially since agreement is found concerning the Cedar Hills age of the prominent red sandstones at the Cimarron River bluffs east of Fairview, Oklahoma, and Green's cross section shows the Hennessey shale of southern Kingfisher County, Oklahoma, including a considerable thickness of strata, referable to the Salt Plain and Kingman sandstone according to the correlations of this paper, in excess of the Hennessey of the type locality.

Subsurface.—In the subsurface, any sand near this approximate horizon is often, and somewhat loosely, labelled Cedar Hills, the more especially if the grains are the rounded, frosted, orange-colored and polished sandstones of erratic distribution, both vertically and horizontally, ranging throughout the Salt Plain-Cedar Hills interval, and greatly resembling certain sands in the Whitehorse formation of Oklahoma, to which Roth[64] ascribes an eolian origin. No beds containing grains of this description have been noticed by the writer in any of the outcropping beds of the Cedar Hills sandstones, or, for that matter, in any of the Kansas Cimarron, although somewhat similar grains are found in the fossiliferous Verden sandstone member of the Whitehorse formation at the type locality in Oklahoma and elsewhere. Some of the sandstones of the Marlow member of the Oklahoma Whitehorse have an eolian appearance in their cross-bedding, but all of the sandstones observed along the Kansas outcrops appear to have been deposited in water.

FLOWER-POT SHALES

The Flower-pot shales were named by Cragin for Flower-pot Mound southwest of Medicine Lodge at the divide between East Cedar Creek and West Cedar Creek in Barber County. In Kansas this formation is confined in outcrop to Barber County with the exceptions of limited exposures along Medicine Lodge River in southeast Kiowa County and along the Salt Fork, west of Aetna, in southeastern Comanche County. Its soft gypsiferous red shales have

[64] Robert Roth, "Custer Formation of Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 4 (April, 1937), pp. 445-47.

been fully and accurately described elsewhere in the literature and because of its distinct lithologic character and juxtaposition to the easily identified Blaine above, it is also readily recognized and consequently is one of the best known formations in Kansas (Fig. 13).

In Oklahoma the writer has seen typical Flower-pot shales underlying Blaine gypsum and dolomite near El Reno and redbeds beneath the Blaine in Texas have been correlated with the Flower-pot.

The following quotations from Cragin[55] adequately describe its characteristic appearance.

> The surface is often strewn with fragments of white, pink, red, or water-clear satinspar flecked with green or red clay, and is sometimes also set off with sparkling crystals of selenite. In canyon walls the satinspar forms a network with irregular rhomboidal meshes—warped plates traversing the clay in all directions—sometimes in specious sublenzitoid compartments subject to partition in various directions by intersecting veins. The seams vary from mere paper-seams to plates several inches in thickness.
>
> A noticeable and picturesque feature of the Flower-pot clays is the manner in which their outcrops are carved by the elements. They are, in fact, a theater of rapid erosion and many weird spectacles present themselves in their relief forms—frequently cut into rather steeply sloped faces having a peculiar pattern of sculpture that is best designated as cave-and-gully erosion.

The thickness of the Flower-pot varies from about 173 feet (according to Knight)[56] at Lake City, where D. A. Holm reported a sandstone lens of Cedar Hills aspect within the formation, to 190 feet southwest of Medicine Lodge, where measured by the writer. Local benches of gypsum or gypsiferous sandstones occur at numerous horizons, especially near the top. Near the middle of the formation a thin dolomite lentil has been noted.

The formation rests on the white sandstone which bears the "snowball" concretions of gypsum marking the top of the Cedar Hills sandstone. The Flower-pot normally is overlain by the basal dolomite bed of the Medicine Lodge gypsum.

Subsurface.—Where traced underground, this formation is recognized in many places, at least in part, although its thickness is variable according to the amount of sandy beds increasing at its expense in the lower part of these strata. The amount of selenite veining commonly varies, and some sections show rock salt at this horizon, which is not strange since saline springs have long been noted along its outcrop in Oklahoma.

[55] F. W. Cragin, "Observations on the Cimarron Series," *Amer. Geologist*, Vol. 19 (1897), pp. 25–26.

[56] G. L. Knight, *op. cit.*

DISCONFORMITY (?)

In the subsurface a horizon of potential unconformity must be recognized at the contact of the Blaine and the underlying beds of the Nippewalla group, especially in western Kansas and eastern Colorado, as shown in Figure 2, the interval between the Blaine and the Stone Corral formations having thinned to 140 feet, as compared with a normal subsurface thickness of about 5 times that amount, and compared with a maximum thickness of 855 feet at the outcrop.

Whether this pronounced thinning off the east flank of the Sierra Grande arch is due to the erosion and removal of pre-Blaine strata, or is a natural depositional thinning, may be left to the future to determine.

At the outcrop little evidence in support of a disconformity at this horizon has appeared, the local variations in thickness being not unreasonable for sediments of the Flower-pot type. Where the Flower-pot becomes deltaic and cross-bedded in the Oklahoma Chickasha, the more evenly bedded Blaine may in some places appear to lie unconformably on it.

BLAINE FORMATION

The Blaine formation is practically identical with Cragin's Cave Creek formation, the latter name having definite priority but the former wider-accepted usage.

Cragin's type locality for this formation is Cave Creek, Comanche County, at the Comanche Cave where

> the Medicine Lodge gypsum occupies a thickness of 25 to 30 feet, the Shimer about a third as much, and the interval of red clay, the Jenkins Clay (named after the former Jenkins postoffice) near Cave Creek, 7 to 10 feet. The upper, or Shimer (so named after the township through which Cave Creek flows), is less constantly developed as a distinct bed of massive gypsum, not appearing at all on the valley of the Medicine Lodge river, so far as observed.[57]

On reviewing the strata exposed in Shimer Township, and southwest, near the Comanche Cave on Cave Creek, the writer finds three principal beds of gypsum normally present, the middle member here being much the thinnest and consequently most apt to be diminished by solution, or its underlying shale separating it from the lower Medicine Lodge gypsum bed, most apt to be obscured by talus or flowage of the gypsum over the shale, so that lacking clear-cut exposures an observer might easily believe the two lower beds to be but one. Consequently it is not possible to escape the fact that three

[57] F. W. Cragin, *op. cit.*, pp. 27–39.

beds exist: the lowermost, the Medicine Lodge gypsum; the highest, the Shimer, ordinarily well exposed in the township of that name; the third, a less prominent lentil sandwiched in "Jenkins Clay."

Inasmuch as all three beds have been misnamed and miscorrelated in Oklahoma, partly due to Cragin's ignoring the more obscure middle bed due to its insignificance in the northern exposures, the

FIG. 14.—View northeast from portal of Comanche Cave, showing Cragin's two principal gypsum beds, Medicine Lodge and Shimer, separated by Jenkins clay. Note thin gypsum in Jenkins clay, here named Nescatunga bed.

writer proposes the name "Nescatunga" gypsum bed for this important middle member, exposed along the creek of that name in

SUBDIVISIONS OF BLAINE FORMATION

Cragin[58]	*Old Oklahoma Survey*[59]	*Noel Evans*[60]	*This Paper*
		Haskew, 4 feet	Haskew, 1 foot
Shimer	Shimer	Lovedale, 13 feet	Shimer, 20 feet
Jenkins clay	Medicine Lodge	Shimer, 13 feet	Nescatunga, 3–9 feet
Medicine Lodge	Ferguson	Medicine Lodge, 25–30 feet	Medicine Lodge, 30 feet

[58] F. W. Cragin, *op. cit.*, pp. 27–28.

[59] C. N. Gould, "Geological and Water Resources of Oklahoma," *U. S. Geol. Survey Water-Supply Paper 148* (1905).

[60] Noel Evans, "Stratigraphy of Permian Beds of Northwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 4 (April, 1931), pp. 410–11.

southeastern Comanche County, which bed occurs between the Medicine Lodge gypsum bed below and the Shimer gypsum bed above, and from each of which it is separated by the respective parts of Cragin's Jenkins clay, as shown in Figures 14, 15, and 16. "Nescatunga" was the Comanche Indian name for the Salt Fork.

E. C. Parker, Robt. McNeely, Ira H. Stein, and Noel Evans[61] in 1928 proved the Ferguson to be identical with the Medicine Lodge

FIG. 15.—View of Blaine gypsums in Sec. 13, T. 34 S., R. 17 W., Comanche County, Kansas, showing double ledges of anhydrite in Medicine Lodge bed, and more prominent development of Nescatunga (middle) bed and higher Shimer bed.

of Kansas. Similarly the Shimer of Kansas can be traced into Evans "Lovedale" gypsum bed of Oklahoma.

In Kansas, the Medicine Lodge gypsum reaches its maximum development in the mines at Sun City, Kansas, where it is 30 feet thick and at Comanche Cave on Cave Creek where this thickness is probably exceeded. Ordinarily there is a bed of impure ripple-marked dolomite at the base of the member, varying from ½ to 1 foot in thickness. Where the overlying gypsum has been removed by erosion, this bed may present the appearance of a sandstone due to solution of the dolomite bond. It is well exposed in southern Barber, Co-

[61] *Ibid.*, p. 409.

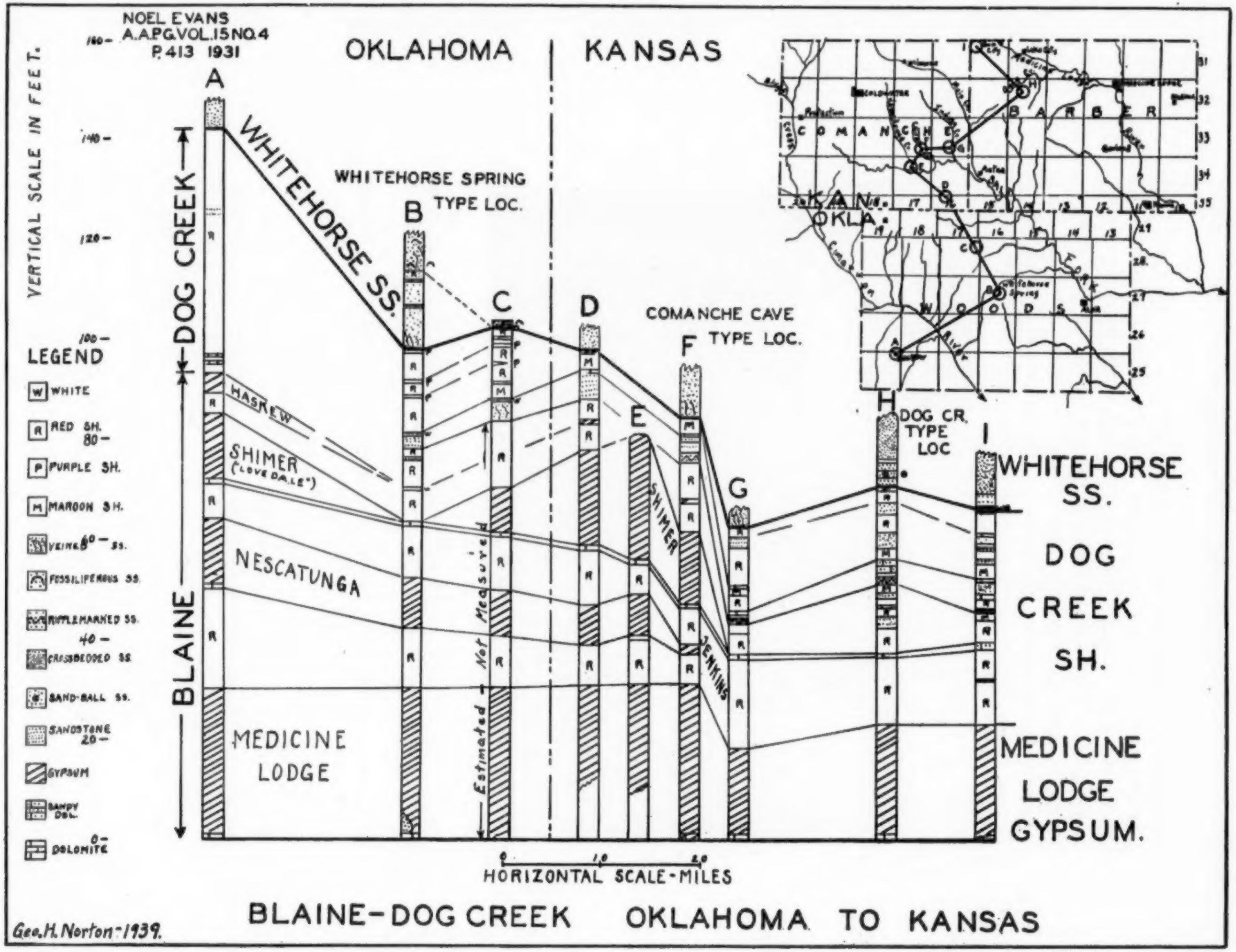


FIG. 16.—Cross section of Blaine-Dog Creek beds from Oklahoma to Kansas.

manche, and Clark counties and its prominent position as a cap rock over the steep slopes of the Flower-pot shale serves to identify it throughout its outcrops. The Medicine Lodge gypsum probably makes the best Keenes cement of the known deposits of gypsum in the United States.

First published recognition, known to the writer, of the middle gypsum bed in Cragin's Cave Creek formation is shown correctly by Moore[62] as a lens in the Jenkins shale, but not mentioned in the text. Later Evans described it, but confused it with Cragin's Shimer.

The Nescatunga gypsum bed is well exposed along the lower reaches of Nescatunga Creek where it is 8 feet thick and separated from the overlying and underlying gypsums by red shale beds of nearly the same thickness. Two miles west, near Liberty School, the member has thinned to 2 feet although protected by several feet of cover. In this area no dolomite occurs at the base of the bed although it is reported present in Oklahoma.

The Shimer gypsum bed, in its type locality, Shimer Township (Ts. 33, 34, and 35 S., R. 17 W.), Comanche County, has a thickness of 24 feet where exposed at the confluence of Nescatunga Creek with Salt Fork Creek, the gypsum here capping a prominent outlier of the Blaine. On Cave Creek, it is at least 14 feet in one good exposure. More commonly it presents an irregular and exceptionally diminished thickness due to excessive solution and erosion. The dolomite beneath this bed varies from $\frac{1}{2}$ to $1\frac{1}{2}$ feet in thickness and ordinarily appears clinkery and weathers to a black grid-work of rectangles as described by Evans[63] for this bed in Oklahoma, his "Lovedale" gypsum bed.

At Southard, Oklahoma, sodium sulphate in quantities sufficient to be undesirable from a commercial standpoint, is found in this member where hydration of the anhydrite is still active. In this connection, it is suggested that a careful study of chemical analyses of anhydrite—preferably cores—would be found helpful in identifying these individual beds where they have not at present been correlated, as from Oklahoma into Texas. Clues to differences of origin might be found such as the occurrences of cyclic salts.[64] Naturally analyses of gypsum are valueless in this connection, since the process of hydration of anhydrite involves solution and recrystallization which necessarily destroys the original connate salt content.

[62] R. C. Moore, "Oil and Gas Resources of Kansas," Pt. 2, "Geology of Kansas," *State Geol. Survey of Kansas Bull. 6* (1920), p. 66.

[63] Noel Evans, *op. cit.*, p. 411.

[64] A. W. Grabau, "Principles of Salt Deposition," *Geology of the Non-Metallic Mineral Deposits* (1920), pp. 155–57.

FIG. 16.—Cross section of Blaine-Dog Creek beds from Oklahoma to Kansas.

Suffel[65] mentions Gould's report of Shimer fossiliferous dolomite in Sec. 1, T. 21 N., R. 14 W., Oklahoma, and Beede's discovery of fossils in dolomite under "Medicine Lodge" (probably Nescatunga) near Ferguson.

The Haskew gypsum member, named by Evans, in few places exceeds one foot in thickness at the southern part of Kansas where it is exposed about 5 feet above the Shimer, red shales separating the beds. At Cave Creek, it is recognized as gypsum streaks in gray shale and sandstone and it is not recognizable in the drainage of the Medicine Lodge River where it is included in the Dog Creek shale as are also the remnants of the Shimer and Nescatunga gypsum members and their underlying shales after loss of the gypsum by solution.

Ever since Rogers[66] discovered that gypsum forms by the hydration of anhydrite, field examination has brought to light in strata of many geologic ages, the fact that most, if not all, of the great commercial gypsum deposits have been so formed in ages past, and hydration still continues. Since this is a metamorphism which is extremely rapid in a geologic sense, so that change may be noted during a life span, this fact, taken with the ease of solubility of the resulting gypsum and salt beds with which it may be associated, gives the geologist important aids in deciphering the geologic history of those beds and their enclosing strata.

Thus in studying the Blaine-Dog Creek sequence of strata in northern Oklahoma and southern Kansas, one is impressed immediately with the great effects of solution on these evaporites but especially so in the Medicine Lodge River drainage where only the lowermost gypsum remains although solution slumpage in the overlying beds bears evidence of the wasting away of important beds once present. Why should there be more solution along the drainage of the Medicine Lodge River at its crossing of the gypsum-bearing outcrops than at other stream crossings of similar drainages farther south? To answer the question, we might postulate an earlier, greater stream than now exists. In this particular instance there are facts bearing evidence corroborating such an assumption. It is commonly believed, due to some water wells in the area which found thick sand deposits where bed rock might reasonably be expected at shallow depths, that the Arkansas River had an earlier channel with its lower reaches in the present bed of the Medicine Lodge River, stream piracy west of the Great Bend in Barton County having since captured the upper

[65] G. G. Suffel, "Dolomites of Western Oklahoma," *Oklahoma Geol. Survey Bull. 49* (1930), pp. 72–74.

[66] A. F. Rogers, "Notes on the Occurrence of Anhydrite in the United States," *School of Mines Quarterly*, Vol. 36 (1915), pp. 124–28.

reaches of the drainage, with the old stream channel left to be buried under Tertiary and later materials. The use of this geologic yardstick, for ground waters and climatic conditions of the past, has been little noted in the literature although the writer has found it useful in north-central Texas where changing climatic conditions during the Pleistocene proved responsible for the break-down of gypsum beds, unlocking their crystals into particles which accumulated (contrary to most published theories of origin) as clastic deposits of gypsum sands and silts to form the large commercial deposits of gypsite. In this connection, Roth[67] ignores the possibility of differential hydration of anhydrite and attempts to make a distinction between the gypsums of the Double Mountain formation of Texas on the basis of anhydrite content, the more hydrated gypsum beds being included in the Blaine and the upper more anhydritiferous beds being placed in the Whitehorse sandstone, a conclusion hardly justified, from the writer's experience, by the evidence.

DOG CREEK SHALES

The Dog Creek shale crops out in eastern Comanche County and western Barber County close above the outcrop of the Blaine gypsums, and disappears under the Cheyenne sandstone (Comanche) in southern Kiowa County.

At the type locality on Dog Creek (Fig. 17), south of Lake City, Barber County, Kansas, the Dog Creek shales include the strata from the base of the overlying Whitehorse sandstone to the top of the gypsums, which in the Medicine River drainage is ordinarily confined to the lowermost or Medicine Lodge stratum. The Dog Creek there is 53 feet thick and includes several layers of dolomite and dolomitic sandstone which, in sections farther south, where not influenced by excessive ground-water solution, are more properly included with the gypsums of the Blaine formation. On Cave Creek, the Dog Creek shales are 23 feet thick, here including the remnant of the Haskew gypsum bed and its underlying shale. Nearer the Oklahoma line, only a few miles south, where the Haskew is a true gypsum bed, although only one foot thick, the Dog Creek is reduced to 14 feet, its topmost member being an exceptional gypsum bed, one foot thick, with wavy red stripings, which is in many places absent due to solution, the porous Whitehorse sandstone immediately overlying the bed and allowing ready access to ground water. This peculiar gypsum bed is underlain by 3 feet of maroon shales which ordinarily mark the top of the Dog Creek in Kansas.

[67] Robert Roth, *op. cit.*, p. 433.

An important sandstone member of this formation immediately underlies the maroon shale. This is 6 feet thick and in places has a cap of ½–1 foot of sandy dolomite which is inconstant and gives place to thin conglomeratic sandstone at the top of the bed. The bed is white or red and in most places the lower half of the bed is particolored. The character of the sandstone is quite different from that of the overlying Whitehorse. It is more of a bench-former because of its

FIG. 17.—Dog Creek shale at type locality on Dog Creek in Sec. 9, T. 32, R. 14 W., on road southwest from Lake City, Barber County, Kansas. Right foreground is Whitehorse sandstone cap rock; center foreground is prominent sandy bench-former in Dog Creek shale; in distance is white Medicine Lodge gypsum and small Flower-pot shale hills.

greater hardness due to a cement of calcareous or gypsiferous material, and does not contain the "sand-balls" characteristic of the Whitehorse. This member can be traced throughout the extent of the Dog Creek shale in Kansas and is of great value in correlation of sections although it has probably been mistaken many times for the sandstone at the base of the Whitehorse, especially where some solution slumpage has taken place beneath and thus confused the normal relations of the strata, as shown in Figure 18.

Evans[68] has suggested the possible equivalency of the thin dolomite

[68] Noel Evans, *op. cit.*, p. 411.

in the base of the Shimer gypsum (his "Lovedale") and the Mangum dolomite of southwestern Oklahoma. It occurs to the writer that a more logical correlation of the Mangum would be with a similar 4-foot bed of dolomite, in places sandy or shaly, which lies 30–40 feet above the Shimer gypsum in the Southard, Oklahoma, area as a member of the Dog Creek formation, which might be correlated also with the prominent dolomitic sandstone here mentioned. At the Dog

FIG. 18.—View in Sec. 29, T. 34 S., R. 16 W., Comanche County, Kansas, showing Medicine Lodge gypsum, Nescatunga gypsum, and Shimer gypsum, with small block of Dog Creek shale dropped in sink-hole to rest on Nescatunga bed.

Creek type locality, its position is only a few feet above the remnantal Shimer dolomite.

Subsurface.—In few places in the subsurface, can the Dog Creek shale be distinguished from the beds of the underlying Blaine because of the increase in gypsum content of the Dog Creek. Actually the Blaine-Dog Creek is a single gypsiferous formation both at the surface and underground, in Kansas, either one thickening at the expense of the other depending on the presence or prior removal of anhydrite or gypsum. In the subsurface, if the gypsum content is 50 per cent or more it can be considered to be Blaine; if the upper part of the Blaine is red shale exceeding this percentage, it may possibly be regarded as Dog Creek.

DOG CREEK-WHITEHORSE CONTACT

Above the Dog Creek shales and their interbedded dolomites and gypsums lie the bright-red sandstones of Cragin's "Red Bluff beds," later named "Whitehorse sandstone" by Gould,[69] the former name being pre-occupied.

The lowest member of the Whitehorse sandstone, the Marlow member of Sawyer,[70] appears to lie conformably on the Dog Creek shale in Kansas, judged by the evidence of undisturbed beds. This agrees with the opinion of Evans[71] for the related area in northwestern Oklahoma.

This does not agree with the ideas of many geologists who have studied these strata, especially in Oklahoma, who believe there is a major unconformity at this horizon. In 1920, Moore[72] wrote: "Recent studies chiefly by Beede . . . indicate that a very important unconformity exists at the base of the Whitehorse sandstone." No proofs are given.

Since then many geologists working in Oklahoma have interpreted field evidence to support this conclusion, based largely on the thinning and thickening of the Dog Creek shale, and a possible overlapping of the Whitehorse over supposedly truncated older beds, as more recently outlined by Brown.[73] In the discussion of this paper, Schweer[74] interprets the same evidence as lateral gradation of the Dog Creek sediments.

In an attempt to prove the Triassic age of beds above this horizon, Roth[75] appears to have been in error in describing an angular unconformity at the Whitehorse-Dog Creek contact in Sec. 18, T. 30 S., R. 15 W., Barber County, Kansas. At this locality the Comanche Cheyenne sandstone rests unconformably on redbeds, probably on both Whitehorse and Dog Creek. In some gypsum quarries along the highway at about that point Dog Creek beds are slumped down into the gypsum beds where the latter have been dissolved. Knight[76] also failed to find any evidence of unconformity at this locality. The writer knows

[69] C. N. Gould, "Geology and Water Resources of Oklahoma," *U. S. Geol. Survey Water-Supply Paper 148* (1905).

[70] Roger W. Sawyer, "Areal Geology of a Part of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, No. 3 (1924), pp. 312–20.

[71] Noel Evans, *op. cit.*, p. 419.

[72] R. C. Moore, *op. cit.*, p. 71.

[73] Otto E. Brown, *op. cit.*, pp. 1547–51.

[74] *Ibid.*, Discussion by Henry Schweer, p. 1554.

[75] Robert Roth, "Evidence Indicating the Limits of Triassic in Oklahoma, Kansas, and Texas," *Jour. Geol.* (November–December, 1932), p. 713.

[76] G. L. Knight, *op. cit.* (1929).

of no locality in Kansas or northern Oklahoma where positive evidence of pre-Whitehorse erosion is to be found. Locally there is much slumpage of the Dog Creek and even of overlying Whitehorse strata directly related to solution of the gypsum beds of the underlying Blaine, giving a variety of abnormalities which may be readily discounted by geologists familiar with the peculiarities common to evaporite outcrops, but which may be carelessly interpreted as "disconformity." Figure 18 illustrates the appearance of a block of Dog Creek shale dropped into the gypsum beds of the Blaine, making such a "false disconformity."

Kiger Division

Overlying the Dog Creek shale, the highest divisible unit of the Salt Fork division of the Cimarron, and with the matter of its conformity in question, begins the Kiger division of Cragin, from the Whitehorse sandstone at the base to the Big Basin formation at the top of the exposed Permian, where it goes under the Cretaceous and Tertiary overlaps.

WHITEHORSE SANDSTONE

In Kansas the Whitehorse sandstone can be divided into four characteristic members: Marlow member, Relay Creek dolomite member, an even-bedded sandstone member, and an upper shale member, the latter two representing the Rush Springs-Cloud Chief members of the Oklahoma section. As the Cloud Chief gypsums have not been reported or observed by the writer in the Kansas section, this member, as such, is not recognized. Obviously most of the "Cloud Chief gypsums," so-called, are individual gypsum beds developing above the separate thin dolomites of the Rush Springs, and above the Day Creek dolomite, and can scarcely be regarded as a distinct and separate formation, and may better be described by individual beds as originally named: Cyril dolomite and gypsum, Weatherford dolomite and gypsum, *et cetera*.

Marlow member.—The basal 110 feet of sandstone overlying the Dog Creek shales is a unit of poorly bedded, soft, ordinarily fine-grained, commonly cross-bedded sandstone, very difficult to subdivide into its individual layers. It weathers into deep canyons and massive bluffs. Locally some of its more resistant beds are composed of masses of "sand-balls," to be described in succeeding pages. Many of the basal beds are prominently cross-bedded. In places they are more shaly or silty and some are veined. That this member is the Marlow was recognized by Darsie A. Green.[77] Figure 19 shows typical topography of the Kansas Marlow member.

[77] Darsie A. Green, *op. cit.*, p. 1526.

Relay Creek dolomite member.—Capping the bright red bluffs of the Marlow is a variable member of sandstone 22 feet thick, with a dolomitic bed, ranging from a few inches to a foot in thickness, at top and bottom. Locally either or both of these dolomites alter to anhydrite or gypsum, which may then dissolve, leaving the horizon

FIG. 19.—Typical Marlow exposure in southeastern Comanche County, Kansas. Cap rock is cross-bedded, calcareous sandstone of Relay Creek horizon. Flat topography in distance is Blaine.

marked with a prominent white bed of sandstone or sandy shale. In southeastern Comanche County (Fig. 20) the dolomites are associated with a peculiar cross-bedded, very calcareous, white sandstone, the dolomite lying on the top of the cross-bedded sandstone which holds up the bench. This sandstone is much coarser than the ordinary

red sandstone of the Whitehorse and where present the bed is readily identified. In places there is but one of these beds, the other not being sufficiently developed for recognition. Locally the bed thickens to 5 or 6 feet or more at the expense of the underlying red sands. The horizon is of great stratigraphic value and makes a good datum for structural mapping. In central and northern Clark County these beds are recognizable only as white streaks in the redbeds above a mass of featureless red sandstones, and below the next evenly bedded sandstone

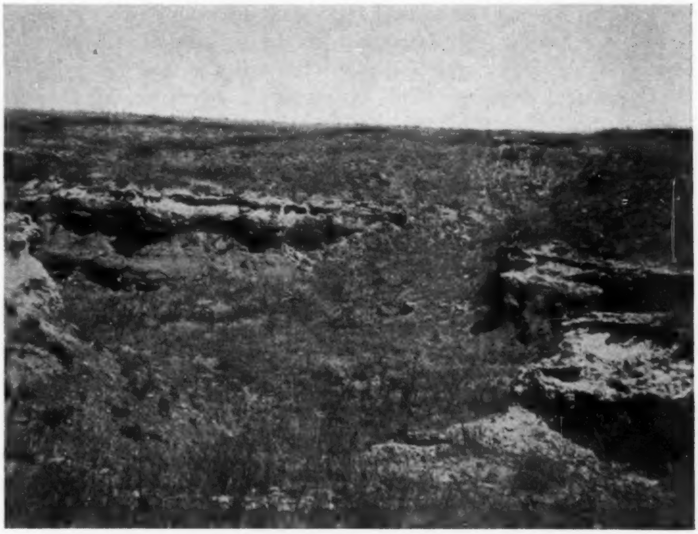


FIG. 20.—Prominent cross-bedded, white, calcareous sandstone of Relay Creek dolomite horizon, with upper dolomitic ledge 22 feet above, making second bench. View in SE. ¼ of Sec. 12, T. 33 S., R. 17 W., Comanche County, Kansas.

member. These dolomites are provisionally correlated with the Relay Creek dolomites.[78] In Oklahoma the Relay Creek dolomites are regarded as being the upper part of the Marlow.

Even-bedded member.—Overlying the horizon of the Relay Creek dolomites and related beds is 100 feet of well bedded sandstones with thin intervening shaly siltstone partings which also weather into canyons and promontories, but unlike the Marlow below, the individual beds of this member can be followed and correlated from place

[78] Noel Evans, "Stratigraphy of Permian Beds of Northwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 4 (April, 1931), p. 416.

to place across the area of the Kansas outcrop, from the type locality of Cragin, in the drainage of Bluff Creek, west of Protection, Comanche County, southwest into Clark County and southeast into southern Comanche County again. One of the more prominent and thicker sandstone beds has a deeper maroon color than the average and makes a good correlative marker. "Sand-balls" are present in these strata also, and the "sand-crystals" from which they developed were found in the lower beds of the member. Probably the best exposure of this member is in the Morrison oil field of Clark County, west of Protection. The highest bed exposed here is extremely cross-bedded and may be correlated with the heavy sandstone benches 38 feet below the Day Creek dolomite a few miles west.

Upper shale member.—The 38 feet of shale intervening between the even-bedded member and the Day Creek dolomite is a very distinctive unit of the Whitehorse and is deserving of further study. Close to the base is a dolomitic horizon of two or three members, each about ½ foot thick, bedded in maroon clay shale. Calcite crystals of good size are present in an interlocking mass in the intervening shale. Above are some brick-red sandy clays, another calcareous sandy lentil near the middle of the member, a thin, hard, red sandstone, more soft red sandstones, a last thin maroon shale, and above that 4–7 feet of gray-green sandy shale, more buff-colored immediately beneath the contact with the Day Creek dolomite. These beds are well shown in Figure 23.

Verden sandstone.—The so-called "channel-sands" of the Whitehorse, according to Sawyer,[79] were first referred to as a fossil stream channel by J. W. Beede and V. V. Waite, working independently for the Oklahoma Geological Survey, and Frank Reeves[80] followed their interpretation. Reed and Meland[81] and Stevenson[82] named it and mapped its areal distribution, while Clifton[83] and others have collected fossils, first noted by Gould and studied by Beede. Roth[84] has listed these fossils, questioning their Permian age. Bass believes the Verden sand to be some sort of barrier beach, an offshore bar or spit.[85]

[79] Roger W. Sawyer, *op. cit.*, p. 319.

[80] Frank Reeves, "Geology of the Cement Oil Field, Caddo County, Oklahoma," *U. S. Geol. Survey Bull. 726-B* (1921).

[81] R. D. Reed and Norman Meland, "Verden Sandstone," *Jour. Geology*, Vol. 32 (1924), No. 2.

[82] C. D. Stevenson, "Observations on the Verden Sandstone of Southwestern Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9, No. 3 (May–June, 1925).

[83] R. L. Clifton, *op. cit.*, p. 169.

[84] Robert Roth, *op. cit.* (1932), p. 716.

[85] N. W. Bass, "Verden Sandstone of Oklahoma—An Exposed Shoestring Sand of Permian Age," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 4 (April, 1939), pp. 559–81.

The sandstone itself is pinkish and composed of fine and coarse grains, the latter commonly rounded and frosted. At Whitehorse Springs (Fig. 21), west of Alva, Oklahoma, the cross-bedded, fossiliferous bar-sand is approximately 100 feet thick with only a few feet of normal type Whitehorse separating it from the shales of the Dog Creek. Close to the principal spring at the foot of the outlier the base of the bar-sand seemed to be interrelated with a sort of solution-

FIG. 21.—Whitehorse sandstone at type locality, Whitehorse Springs, Woods County, Oklahoma. Sandstone is cross-bedded, richly fossiliferous, and exhibits "channel-sandstone" facies, as do also small buttes in distance (south). This appears to be thickest (90 feet) Verden sandstone reported.

breccia cemented by veins of calcite or calcitic sand with the general appearance suggesting the sandstone replacing salts once present, but whether before the consolidation of the sediments, or after, was not discernible from a brief study. Between this point and the Kansas line (Fig. 16, section C), the fossil-bearing sandstone rests directly on the Dog Creek shale, but appears to be only a foot or so thick, and has beds in close proximity which appear to be normal Whitehorse immediately above it. No sands of this type, however, have been found by the writer in Kansas. The cross-bedded white, calcareous sandstones related to the Relay Creek dolomites most nearly resemble

them in general characteristics but appear to be without fossils. In Oklahoma and Texas the bar-sands occur at different horizons, some at the horizon of the Relay Creek dolomites and some lower in the Marlow and some in higher beds.

Some of the sand grains of the bar-sands resemble somewhat the orange-polished sands of the Kansas subsurface, which are found at the Whitehorse and Cedar Hills-Salt Plain horizons, for the most part. Their source and origin are obscure, and most of the evidence concerning these is disputable. The writer has little to add toward the solving of the puzzle. In the area here studied, the orange-polished sands, regardless of the horizon in which they are found, are best developed in extreme western Kansas and eastern Colorado. This is evidence of a western source. In the entire Kansas geological section, sands of a somewhat similar appearance and color are found only in the detrital part of the Marmaton, in association with the red rock. These grains are somewhat similarly rounded, polished, and stained, although for the most part the staining is deep red and not orange. Here and there, however, an orange tint is noticed. It seems barely possible that over the Sierra Grande arch (Fig. 2), or other parts of the Ancestral Rocky Mountains, the post-Pennsylvanian-pre-Permian uplift might have exposed red Marmaton sands to erosion, their grains already rounded and stained, and subsequent transportation by air or water, or both, could have resulted in the altered color of the pigment and higher polish.

Sandballs.—One characteristic feature of the Whitehorse sandstone which has escaped published mention is the general presence of "sand-balls" on weathered exposures of the sandstone beds. These balls vary in size from the size of a large pea to that of bird-shot, the larger ones commonly containing large rounded frosted sand grains. These small balls of sandstone, ordinarily clustered together, make up large parts of some very prominent ledges southwest of Sun City, Barber County, and also in eastern Comanche County, and have been found from the base of the Whitehorse sandstone in contact with the Dog Creek shales, up through all members of the Whitehorse and within a few feet of the Day Creek dolomite at the top of the formation. This peculiarity gives a useful clue to the age of such "sand-ball"-bearing sandstones since they have not been noted in strata below or above the Whitehorse.

The origin of these rounded clusters was in doubt until a cluster of "sand-crystals" (Fig. 22) was discovered at about the middle of the Whitehorse, which appeared to be red sand pseudomorphic after calcite in an exceptional hexagonal form. Some specimens of these "sand-

crystals," partly rounded, and at a mid-stage of wearing down to "sand-balls," can be recognized while embedded in the same slab of rock with fully rounded specimens. It seems probable to the writer that the "sand-crystals" have been subjected to wear by rolling action, presumably by water rather than by air, and thus assumed the rounded form of the "sand-balls," becoming smaller and smaller as wear continued until buried by succeeding sand deposition.

In the red silts of that desert laboratory which was the site of the Whitehorse deposition, along with dolomite, anhydrite, gypsum, and

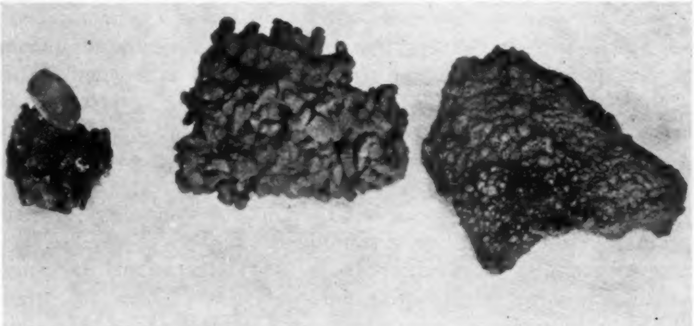


FIG. 22.—Center rock is intergrowth of "sand-crystals" from Whitehorse sandstone in southeastern Comanche County, Kansas, compared with mass of "sand-balls" from same locality, partly or wholly worn down from crystal shape. Sand crystals contain much calcite, and have taken exceptional crystal form similar to larger individual calcite crystal collected from Joplin district in Missouri by Leslie M. Clark.

barite, were formed countless crystals of sand, pseudomorphic after calcite, which after attrition to "sand-balls" were to make up an appreciable quantity of the deposited material. The dolomite beds occur at the approximate horizon of the Relay Creek dolomites of Oklahoma, and locally grade into gypsums which become anhydrite under load of overlying beds. The barite observed near Protection occurred at the same general horizon as the dolomite zones, but at the north extension of the outcrop of this formation, where the dolomitic zones were expressed only by prominent white streaks in the red siltstones with the following change from south to north at that approximate horizon: dolomite with calcareous, cross-bedded sandstone; to gypsum or anhydrite associated with white sandstone beds; to calcite crystals; to barite geodes and nodules.

Large calcite crystals also occur in the maroon and red shale separating the two thin dolomites 35 feet below the Dog Creek dolomite

which is an exceptional and easily identified horizon previously mentioned by Clifton and Evans.

The amount of calcium-charged waters in the Whitehorse seas must have been abnormally large, and where these were further concentrated to the point of precipitation, crystals formed; where these waters were in quicksand the crystal structure developed, embodying the enclosed silts and sand. Although the sand-crystals pictured are red as any red rock, a spectroscopic analysis made through the courtesy of Eldon A. Means, of the Eldon Means Laboratories, Wichita, Kansas, showed the principal mineral to be calcite, with minor amounts of silica and iron, the latter probably as a pigment.

Subsurface.—In the subsurface of western Kansas, the Whitehorse sandstone is commonly indistinguishable from other redbeds, as shown in the cross sections (Figs. 2 and 3), save for its juxtaposition with the overlying Day Creek dolomite or with the underlying Dog Creek-Blaine formation. Locally some of the orange polished and rounded sand grains emphasized by Roth can be found in the well cuttings from this formation but they do not maintain a constant stratigraphic level. They become prominent at different levels in separate, adjacent, and easily correlated wells. The exceptional thickening of this formation southwestward into west-central Oklahoma, where the included gypsums, anhydrites, and dolomites of the Cloud Chief member become prominent, together with the broken character of these outcropping redbeds, readily explained by deep-seated slumping, suggests not only that gypsum, anhydrite, and dolomite have been added to the section basinward, but also that much rock salt has been present, which being removed by solution while under cover, has caused the pronounced and erratic slumpage of the overburden. This action appears to have taken place in Kansas also, west of the outcrops of the formation, the Big Basin and other sink-hole areas of southwestern Kansas being developed by the caving-in of the surface beds to the caverns developed in the Whitehorse beds from which the included salt has been removed (Fig. 24).

Age of the Whitehorse.—Recent papers rather conclusively re-establish the Permian age of the Whitehorse formation. As summarized by DeFord:[86] "The gradation of Whitehorse into Capitan disposes of the untenable theory that the Whitehorse is Triassic. Yates sand passes beneath beds containing Permian (Guadalupian) fossils." The Whitehorse of that region has been divided from the base upward into

[86] Ronald K. DeFord, "Surface and Subsurface Formations, Eddy County, New Mexico," abstract, paper read before the Association at the El Paso, Texas, mid-year meeting, September 27 to October 2, 1938.

Grayburg limestone, Queen sand, Seven Rivers gypsum, Yates sand, and Tansill limestone. The upper three (possibly the upper four) are equivalent to the Capitan limestone. They grade into thin-bedded Carlsbad limestone which grades into massive Capitan limestone, and the Capitan, in turn, grades into upper Delaware Mountain sandstone.

Corroborating this stratigraphic evidence of Permian age are the careful paleontologic studies of Newell, Knight, Moore, and Brill,[87] who conclude that "the fossiliferous beds (Whitehorse) . . . are certainly late Permian in age. Evidence, both faunal and stratigraphic, indicates at least partial equivalency with the Carlsbad limestone of southeastern New Mexico."

DAY CREEK DOLOMITE

The Day Creek dolomite, overlying the Whitehorse sandstone, has been described by Cragin, Clifton, Evans, and others.

In Kansas it is a single bed, typically about 2 feet thick, of fine-grained dense dolomite, overlain and ordinarily underlain by gray shales. In Oklahoma, Evans found a thinner second bed a few feet above the principal bed and suggested that there might also be two in Kansas. Excellent exposures in the region of Ashland, Clark County, near its type locality, fail to show more than one bed. The writer has never seen two beds in Kansas, but it may be possible to find two beds at exposures closer to Oklahoma in areas not observed by the writer. Figure 23 shows some outliers of Day Creek dolomite capping buttes.

In local areas, the dolomite has been partly altered to a siliceous rock which Cragin dignified by the name of "faresite." Several other explanations have been advanced for this silicification, but the writer believes the preponderance of evidence favors the theory of replacement of dolomite by silica from percolating ground water from overlying strata, the commonest source being the sandy conglomerate of the Tertiary Ogalalla "mortar beds." Where these "mortar beds" rest on Smoky Hill chalk in northwestern Kansas, a familiar sight at the contact is the greenish or brownish chertified masses of chalk, in places with fossils intact, ranging from several inches to several feet thick. The "faresite" does not show these same colors, but it is not unreasonable to believe the same source to be primarily responsible. "Mortar beds" are commonly exposed in areas adjacent to Day Creek outcrops although in the areas where "faresite" is best developed little or no

[87] Norman D. Newell, J. Brookes Knight, Raymond C. Moore, and Kenneth Brill, "Invertebrate Fauna of the Late Permian Whitehorse Sandstone," abstract, paper read before the Association at the Oklahoma City, Oklahoma, meeting, March 23, 1939.

cover remains over the prominent dolomite ledge. The fact that the bed is either exceptionally cherty or practically chert-free suggests the secondary nature of the silica present.

Correlation.—The writer does not know of any fossils being found in this bed. It has been correlated with the Alibates dolomite of the Texas Panhandle, resulting in the dropping of that name, and less conclusively with an upper one of the Chaquaco[88] limestones of

FIG. 23.—Buttes about 10 miles north of Freedom, Oklahoma, a few miles south of Kansas line, showing cap rock of Day Creek dolomite over soft shales of upper Whitehorse sandstone. Lower massive ledges are sandstone; shale and sandstone together are probably Rush Springs-Cloud Chief.

southeastern Colorado, the "crinkly limestones" of northeastern Colorado, the Forelle limestone of Wyoming, and the Minnekahta limestone of the Black Hills. Its lithologic character, crinkly wrinklings, color, and topographic expression favor these correlations.

Subsurface.—In the subsurface, it is predominantly chert-free and the lithologic character identifies it. Only few wells in Kansas have encountered this higher dolomite-anhydrite stratum, the post-Permian erosion having removed the bed from the larger part of the state.

In at least one western Kansas well (Fig. 3) anhydrite and gypsum

[88] George O. Williams, personal communication.

are associated with this bed, as is to be expected of all Permian dolomites when traced basinward in the subsurface.

BIG BASIN FORMATION

Overlying the Day Creek dolomite are 65 feet of Permian redbeds which Cragin named Hackberry shales and Big Basin sandstone. The name "Hackberry," being pre-occupied, has been dropped but "Big Basin" has been retained, and because these strata can be considered one formation of sand beds interstratified with beds of silty and sandy shale, the writer considers them to be essentially one formation and includes all beds between the Day Creek dolomite and the top of the Permian redbeds of Kansas (here covered by Cretaceous) under the name "Big Basin formation." While the lowermost 25 feet of the formation is silty shale, similar beds are found in the Harper, Cedar Hills, and Whitehorse sandstones.

Should further work establish the correlation of the lower shaly part of the formation with the Doxey shale member of the Oklahoma Quartermaster formation, the Big Basin name would be restricted to the sand beds alone, the possible equivalent of the Elk City sandstone member of the Quartermaster. At present, however, the inter-relations of the type Quartermaster with the Day Creek dolomite and so-called "Cloud Chief" member of the Whitehorse have not been definitely established; therefore the writer believes that Evans[89] was not justified in attempting to drop the Kansas nomenclature, which has the distinct advantages of priority and ready reference to the enclosing strata.

The basal 7 feet of the lower shaly member of the formation, immediately overlying the Day Creek dolomite, is gray-green in color at some localities, notably at the best known, well exposed section of the formation several miles northwest of Ashland, Clark County, on the road to Minneola near the center of the west line of Sec. 14, T. 32 S., R. 23 W., suggesting its nearer relationship with the underlying dolomite than with the overlying redbeds, inasmuch as the 4 feet of shales immediately underlying the Day Creek dolomite at this location is also of the same color. It is in the horizon of these green shales that the upper bed of the Day Creek dolomite develops on tracing that prominent scarp-former into Oklahoma, as noted by Evans, although he reports brown shale, weathering maroon, separating the two members.

The upper and more prominent part of the Big Basin sandstone consists of 40 feet of sandstones and sandy shales, both locally lithified

[89] Noel Evans, *op. cit.*, p. 429.

to a varying extent. The massive sandstones are normally cross-bedded, red and hard, with a crystalline sheen along a freshly broken face as if bonded with gypsum or some form of calcium carbonate. Three principal beds make bold cliffs, the lower 5 feet thick, the top one 8 feet thick, and an intermediate bed 2 feet thick. Locally, as reported by Cragin, a bed may be leached white in a horizontal band,

FIG. 24.—Jacob's Well, western Clark County, Kansas, typical sink-hole near the Big Basin. Notice small filled sink near other rim of basin. Rim-rock of Ogalalla "mortar-beds" has been dropped down to level of Big Basin formation.

probably by the surface waters from the once overlying Tertiary or Cretaceous. Between these principal sandstone beds, the shales become more or less sandy from place to place.

At the 17th Oklahoma Geological Field Conference, April 10 to 13, 1930, led by C. N. Gould, he reported vertebrate remains from the Hackberry shales, but gave no references or particulars. The writer has not seen any fossils in the Big Basin sandstones.

CONCLUSIONS

The principal conclusions reached after a review of the Permian redbeds of Kansas are the following.

1. Unbounded admiration is due the pioneer work of F. W. Cragin, who, almost a half century ago, by horse and buck-board, and on foot, traversed the semi-desert of the mid-continental redbeds, completing their stratigraphic classification. Inasmuch as this classification has withstood the test of time despite the great quantities of subsequent information, through the detailed mapping and measuring of outcropping strata and through subsurface records of hundreds of wells and core-holes, it is fitting that his names for these subdivisions should be perpetuated here in enduring recognition of his keen perception and scientific labor.

2. Cragin's Harper sandstones, which are shown to include an important dolomite-anhydrite-salt series of formational rank, has been restricted, with the exclusion of the lower formations, named the Ninnescah shale and the Stone Corral dolomite-anhydrite.

3. The most important and definitely recognizable units of the 1,732 feet of Cimarron redbeds studied in surface and subsurface are the three dolomite-anhydrite formations: the Stone Corral, the Blaine-Dog Creek, and the Day Creek. Regional correlations may be established on these with confidence. Intervening red sandstones and shales are extremely variable. Nippewalla is a name introduced for these variable beds between the Stone Corral and the Blaine.

4. There is scant proof of any major unconformity in the Kansas redbeds. In Colorado, over the Sierra Grande arch, considerable marine and red Permian are lacking, with beds of lower Nippewalla resting on the supposed top of the Pennsylvanian, marking the Permo-Pennsylvanian unconformity.

5. Local unconformity may exist close above and below the key dolomite-anhydrite formations, but most of the irregularities at these horizons are due to lateral gradation or solution slumpage. Rapid changes in thickness with apparent conformity are displayed by the Ninnescah shale.

6. The Blaine-Dog Creek may properly be considered one formation in Kansas, either part thickening at the expense of the other, dependent on the presence or absence of soluble gypsum beds. The gypsum bed in Cragin's Jenkins clay, previously miscorrelated and unnamed, is given the name Nescatunga.

7. The Marlow and Relay Creek dolomite members of the Whitehorse sandstone are believed present in Kansas. No Cloud Chief gypsums are known; consequently the upper Whitehorse is considered to be equivalent to the Rush Springs member.

DISCUSSION

Ronald K. DeFord, Midland, Texas (discussion received, July 24, 1939). It is a commonplace view that "unconformity" is synonymous with

"erosion." The presence of unconformities inferred from very sound evidence is doubted or denied because of the lack of convincing field evidence of erosion. Erosion, I believe, is not an indispensable criterion of unconformity, and proof even that erosion did not take place is not a fatal criticism. "Unconformity" means hiatus—that is, elapsed time of non-deposition.

> The absence of a break in a sequence implies, and is a consequence of, continuous deposition. Deposition in shallow waters probably is continuous for only brief intervals, and interruption seems to be the normal and usual fact, such interruption ranging from brief cessation of deposition to intervals of many years, and at the upper limit to erosion or the reverse of deposition.[90]
>
> The magnitude of an unconformity can be measured only by the duration of the lost interval. . . . Neither the prominence of the unconformity nor the coarseness of the sediments which lie upon it is indicative of its importance or duration.[91]
>
> Fossils and the missing strata afford the only clues, and the former are not always reliable.[92]

We are taught that when the surface of a land becomes a peneplain erosion almost ceases. If, in the process of sedimentation, deposition should pause, the top of the last formation deposited would not be a *pene*plain but a *plain*, and without warping, large uplift, or deep withdrawal of the sea marked erosion would be unlikely. The evidence in the stratigraphic column of such pauses, some lasting through epochs marked by the deposition of thick formations elsewhere, is convincing.

Let us, for the purpose of this discussion, divide unconformities into angular unconformities and disconformities, and, following Twenhofel, define an unconformity as a hiatus represented by the *absence* of at least a formation. A hiatus representing less than a formation is called a diastem.

In the light of these definitions, of detailed knowledge of the Delaware basin, and of a general view of Oklahoma and Kansas geology gained from publications and field trips, West Texas geologists confidently believe that the Permian section of Oklahoma and Kansas contains at least two unconformities.

The Delaware Mountain sandstone is composed of three parts: lower, middle, and upper. The lower part, comprising more than 1,000 feet of sediments, pinches out against a marginal ridge on the north side of the Delaware basin. Its equivalent may be present in and south of the Midland basin, but it is absent from the section in the rest of Texas, New Mexico, Oklahoma, and Kansas. The tracing of beds northward through the subsurface supplemented by paleontologic evidence seems to indicate that the hiatus representing the missing section in Oklahoma and Kansas is between the Whitehorse and the Dog Creek.

The lower Castile formation, in places composed of 1,700 feet or more of salt and anhydrite with laminae of limestone, is confined to the Delaware basin. The upper Castile, Rustler, and Dewey Lake, which attain a total thickness of as much as 2,500 feet in the basin, extend beyond the basin into surrounding territory. Many West Texas geologists interpret the evidence to indicate that these beds pinch out in the subsurface within the boundaries of Texas and New Mexico and are therefore absent in Oklahoma and Kansas.

[90] William H. Twenhofel, *Treatise on Sedimentation*, 2d edition, p. 625.

[91] *Ibid.*, p. 631.

[92] *Ibid.*, p. 632.

The hiatus that represents the absence of at least the lower Castile, and probably also the upper Castile, Rustler, and Dewey Lake, appears to them to be between the Quartermaster and the Whitehorse in Oklahoma, and probably between Norton's Big Basin and Day Creek in Kansas. An increasing opinion (Adams, Green, Griley, and others) tends toward placing the Quartermaster in the Triassic and making this hiatus the boundary between the Paleozoic and Mesozoic.

Darsie A. Green, The Pure Oil Company, Tulsa, Oklahoma (discussion received, October 16, 1939).—Norton has given an excellent description of the lithology of Cragin's Cimarron series in southern Kansas. He has established definite limits for the Salt Plain formation and has done a commendable thing by restricting the base of the Harper sandstone to a good sedimentary break which extends far southward in Oklahoma. Excepting some minor variations in color, the sediments below the Stone Corral dolomite are of the Wellington type; therefore, it is doubtful if a series boundary should be drawn at the base of his Ninnescah shale.

Lithologically and structurally the Flower-pot shale is more closely associated with sediments above than with the sandstones below the Flower-pot. In Oklahoma the Dog Creek-Blaine and Flower-pot have been included in the El Reno group since 1928. This same grouping is also being followed in north Texas where sediments of the same ages are included in the Pease River group: a term which probably will be dropped in favor of El Reno.

The Whitehorse units described in Kansas do not fit with the details of the Whitehorse group in Washita County, Oklahoma, where the interval from the base of the Marlow to the base of the Doxey shale is three times as long as the interval between the same two contacts in southern Kansas. Oklahoma geologists are pretty well in agreement that the Hackberry shale and Big Basin sandstones of Cragin's original classification form a part of the Doxey shale, which extends across Oklahoma far into Texas. I shall offer no suggestion concerning the correlation of our Cloud Chief and Rush Springs formations with the Kansas section. The Marlow formation is recognizable in western Barber and southeastern Kiowa counties, Kansas. Norton's descriptions of the Marlow and the Relay Creek dolomites suggest that he has not properly identified either in Kansas. In the two counties here mentioned, the thickness of the Marlow formation is only about 65 feet. Here, as everywhere in Oklahoma, the Relay Creek dolomites are included in the upper part of the Marlow formation.

The unconformity at the base of the Marlow is difficult to detect except in Grady, Stephens, Caddo, and Washita counties, Oklahoma. According to my information, the unconformity at the base of the Marlow has been recognized by every geologist who has had the opportunity thoroughly to map these counties.

Cragin's classification has always been useful to Oklahoma geologists and the more detailed descriptions of the stratified Kansas section make it even more useful. In central Oklahoma most of the Kansas formations grade into other units whose boundaries do not coincide with the Kansas formations; consequently, Kansas terms are not applicable. Since no type section is applicable to the sediments in the various Oklahoma counties, our stratigraphy can best be shown graphically. In order to describe the age of any set of sedi-

ments in Oklahoma we refer to the better stratified units well known in the Kansas section.

The top of the lower Hennessey, "the Fairmont shale member," is approximately the top of the Kansas Ninnescah or top of the Stone Corral dolomite. Above the Fairmont member and below the "Bison banded member" of the Hennessey shale, in southern Garfield County, Oklahoma, there is a middle Hennessey member which received no mention when the formation was first described in the literature. This middle member is nearly 200 feet thick and contains many irregular, lenticular sandstones which are entirely different from the lithology of either the lower or the upper Hennessey member. This middle Hennessey is thought to represent all of the restricted Harper sandstone formation of Kansas. The bed at Bison which was first mistaken for Duncan and which Norton has now correlated with his Kingman sandstone is probably well up in the Salt Plain formation. The town of Bison is more than 50 miles south of the Kansas state line and the intervening area is almost entirely covered by loose sand; consequently, it is impossible to trace the outcrop of the Kingman sandstone to southern Garfield County, Oklahoma.

By mapping southward from the outcrop of the Cedar Hills in the river bluffs east of Fairview, Oklahoma, the Cedar Hills is found below the sediments at the town of Okarche (Sec. 32, T. 15 N., R. 7 W., Kingfisher County, Oklahoma). Norton has miscorrelated the Duncan sediments at Okarche with the Cedar Hills of Kansas. The term "Duncan-Chickasha" should not have been affixed to my section (T. 20 N.) since the southern deltaic facies do not extend so far north.

When it is understood that the Duncan wedge is a great deltaic tongue and that the base of this tongue is much younger in Kingfisher County than in Stephens County, Oklahoma, it may be realized that the oldest Duncan facies in the southern area may be Cedar Hills in age while the Duncan sediments at Okarche are Flower-pot in age. It should also be remembered that, while the youngest Duncan near Okarche is Flower-pot in age, the youngest Duncan northwest from Marlow, Stephens County, Oklahoma, is Dog Creek in age. Attempts to divide the Duncan deltaic wedge into formations have resulted in confusion.

George H. Norton (discussion received, October 20, 1939).—A few comments may help to clarify some points discussed by Mr. Green. In spite of some similarity in lithology, the very red Ninnescah and the very dark gray gypseous Wellington make, at their contact, a good boundary over a very wide area, whether or not it may bound a series.

In Kansas there seems no good reason to group Dog Creek-Blaine and Flower-pot in an "El Reno group."

The Doxey-Big Basin correlation, while probable, may still be in doubt, considering frequent questions as to the Triassic age of the Quartermaster. If Permian, it should be Big Basin.

The Marlow is not fully exposed in western Barber County, Kansas, and unfortunately the writer failed to check Mr. Green's Kiowa County section. The thicker full section can be measured in Comanche County. The associated dolomites, tentatively correlated with the Relay Creek dolomites, may not be actual correlatives but they do occupy a relatively similar position stratigraphically and it may be difficult to prove that they are not.

With more detailed stratigraphic work the Kansas boundaries of the redbed units can be recognized farther and farther into Oklahoma. The mid-Hennessey irregular, lenticular sandstones, mentioned by Mr. Green, are certainly in the lower Chikaskia, the upper Chikaskia being the "Bison banded member." The Bison strata may be followed, and correlated across covered areas, readily to the Great Salt Plain where a 20-mile jump across the Salt Fork alluvium to the Manchester correlatives checks very nicely, almost bed for bed, and the unique canyon-forming topography is the same. The correlation here has been generally accepted for many years.

Some, if not all, of the Duncan sandstones lying between Okarche, Oklahoma, and the SW. ¼, SW. ¼ of Sec. 34, T. 15 N., R. 6 W., are probably equivalent to the Cedar Hills sandstones of Kansas. Perhaps some of the higher beds may be equivalent to the lower Flower-pot of Kansas, and might be called "Chickasha" farther south. The words "Duncan-Chickasha" adjacent to Green's section (T. 20 N), properly disavowed by him, were to indicate the commonly recognized Oklahoma nomenclature. It was not an intention of the present paper to confine all Duncan-type beds to a Cedar Hills age but to show if possible where the better stratified Kansas beds finger into the Duncan and Garber deltaic wedges.

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DRILLING-TIME DATA IN ROTARY PRACTICE[1]

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PART I. INTERPRETATION OF DATA

(BY T. C. HIESTAND)

ABSTRACT

Use of drilling time is not new, but the full use of the method has not been employed until recently. The controlled drilling possible with modern rotary rigs, together with the use of the geolograph, makes drilling-time records dependable to interpret accurate depths of porous formations on the rig floor. This in turn allows the geologists on drilling wells to recommend proper testing of all zones where oil and gas occurs, as penetrated. Drilling-time data assist in getting fuller recovery of cores, in avoidance of undue loss of time running on dull bits, and permit the correction for sample lag so that the log of the well checks with electrical and geothermal charts. Six typical well cases are discussed.

INTRODUCTION

The early cable-tool drilling used "drilling changes" and timing drilling progress as means to recognizing penetration through the alternating hard and soft formations. However, when rotary-tool drilling spread over wide territories the field men soon were aware that the changes of rates obviously depended on mechanical as well as geological factors. In rotary practice the earliest use of drilling time to interpret relative porosity of the beds penetrated was probably the closed-pressure operations for "drilling-in." Core-drilling has been guided considerably by use of variations in drilling time per foot, particularly as to when to cease use of the fish-tail bit and to run the core barrel.

Variations in drilling time per foot were used some ten years ago by numerous geologists in the Seminole district in Oklahoma to make more accurate depth determinations for the top of the Viola limestone and other important beds. David (1)[4] has shown convincingly the importance West Texas operators attach to the drilling time in a district where the thick salt deposits encountered in wells deteriorate the mud fluid and in turn cause the quality of the rotary samples to be

[1] The coöperation is acknowledged of the geologists with the Indian Territory Illuminating Oil Company, who have contributed both data and ideas with regard to drilling-time records of rotary operations in Colorado, Kansas, Oklahoma, Texas, and Illinois. A list of published articles is appended which was compiled with the coöperation of the Tulsa Public Library, Technical Department; the United States Bureau of Mines Library, Bartlesville; the *Oil and Gas Journal*, Tulsa, Oklahoma; and the *Oil Weekly*, Houston, Texas.

[2] Consulting geologist, Indian Territory Illuminating Oil Company.

[3] Geological engineer, Indian Territory Illuminating Oil Company.

[4] Numbers in parentheses refer to the list of publications at the end of this article.

very poor as an average. The method is suited to drilling with oil after the flow string of casing is set. Similar importance is attached to drilling time by Kansas operators, and their district has both salt deposits and cavernous limestone zones to interfere with the return of dependable rotary samples. The recent developments in Illinois have been carried on almost entirely with rotary rigs. The operators have not used prepared mud extensively in spite of the fact that formations do not yield very good constituents to produce the viscosity needed to return rotary samples of good quality. Careful attention to drilling time is virtually necessary to obtain an accurate log under these circumstances; and the method has become almost universal in that territory even for operations where the drilling mud is properly maintained.

Perhaps the two important reasons why the drilling-time method has not been perfected sooner are the inconvenience and lack of dependability of manually recording the time, excluding all the hours and minutes consumed in making connections, round trips, *et cetera*, and the lack of proper rotary equipment to indicate the mechanical variations which would accelerate or retard drilling progress. These two factors have been removed in recent months, with the introduction of the geolograph to record the actual drilling time mechanically, and with maintenance of proper drilling mud; the self-lubricating rock bit; leak-proof, full-hole drill pipe; the modern, accurate weight indicator; and controlled rotary speed.

For several years operators have assigned geologists to be present during drilling operations to secure accurate geological information as drilling progresses. Drilling-time data should be interpreted as operations proceed foot by foot so that the proper tests of the porous formations can be made; such records are therefore kept from the beginning to avoid miscorrelations and in search for evidence of unexpected "sands."

MECHANICAL VERSUS GEOLOGICAL VARIATIONS IN DRILLING

Engineers have been investigating mechanical variations which arise in rotary drilling. The work indicates that many useful results will be obtained, although those so engaged consider that much is to be learned in the future. Instruments very accurate in measuring the weight on the bit are used to avoid accelerating or retarding progress unwittingly; the revolutions per minute of the rotary are observed with the tachometer; and the drill-pipe torque is measured by means of a hydraulic torque coupling built into the pinion shaft of the rotary table. Alcorn[5] has demonstrated that by control of the weight on the

[5] I. W. Alcorn, Pure Oil Company, Houston, Texas, personal communication

bit and the speed of the rotary, the charted torque variations tend to correlate with the minute variations of the Schlumberger chart. Hayward[6] has demonstrated that mud-viscosity variations and drilling-time changes correlate with geological formations; and has perfected a continuous mud-stream sampler to secure samples both at the returns-chute and the intake line to the pumps so that the loss or gain of viscosity is recorded accurately. Such investigations are phases of geophysics beginning with the rotary tools, whereby valuable data are being secured which will confirm information from sample logs, electrical and geothermal charts. The advantages of the data which are supplied in the operations obviously lie in the opportunities afforded the operator to decide immediately at the well what testing of formations is warranted—at no great cost additional to the drilling itself.

To interpret drilling-time data accurately, proper conditions at the well presuppose that mechanical variations are eliminated to the degree of negligibility. The basic differences in rocks which will retard or accelerate drilling progress have to do with relative hardness and porosity. The rock bit chips the rock, the drilling mud exerts hydraulic action to remove cuttings and actually to cut the clay or any water-soluble deposits. Moderate drilling speed in shale which is relatively soft is due to its lack of porosity and tendency to create friction. The slow drilling speed in an impervious limestone is due to its relative hardness as well as lack of porosity. A quartzite with its very great hardness and density drills slowest. At the other extreme, a porous, friable sandstone drills rapidly; the hydraulic action of the mud practically cuts the formation. Porous, leached, vuggy dolomitic limestone, even though cherty, and therefore having relative hardness, drills rapidly due to the high porosity.

David (1) mentions that specific drilling time per foot has a direct relation to the porosity of the Permian limestone in the Goldsmith pool, since nearly constant weight on the bit is used by all the operators. Otherwise, specific time can not be said to be as important as the observation of the greater variations which occur in time records.

The acute acceleration or retardation of drilling rate marks the depth of a formation change; the geologist at the well examines the cuttings as soon as these have arrived at the surface to learn what the formation change is lithologically and whether any staining or odor of oil and gas is present. The very gradual retardation of drilling rate is due to dulling of the bit as a general rule, particularly since the weight indicator has been used as a guide in drilling.

[6] J. T. Hayward, Barnsdall Oil Company, Tulsa, Oklahoma, oral communication.

In cases of operations where the depth reached is several thousand feet the time required for the cuttings to arrive amounts to as much as an hour or longer. When the drilling has been accelerated to a rate of less than 5 minutes per foot, the tools have to be raised off bottom and the samples circulated to the surface for examination or else the hole would be deepened too much (even though a fairly thin oil "pay") before a decision is reached to core or otherwise test the zone.

The question of the proper units to use has been discussed with geologists located throughout the territories where rotary drilling is carried on. The consensus is that the proper unit is minutes per foot, recorded foot by foot. The separation of the geological from the mechanical factors is thus best accomplished. Furthermore, when a very porous formation is reached the depth to the foot is needed. To avoid taking unnecessary cores or tests, that is, where only one or two feet of soft formation has been penetrated, the hole can be deepened in one-foot stages and samples circulated for a sufficient evidence of oil and gas saturation, and thereby be certain in making the decision to core or test.

TIME DATA IN CORING OPERATIONS

Naturally the specific time per foot for coring operations has no direct relation to full-hole drilling rates. The time variations per foot in coring are important in themselves. For example, in the Illinois basin the sandstones of the Chester series have tightly bonded layers alternating with sugary, friable layers; and the limestone beds of the Ste. Genevieve range from very dense to extremely porous, oölitic and soft. Ordinary coring practice has been very successful for the dense beds, but not for the soft ones. The core barrel, having become loaded with the dense material, acts as a drilling bit and pulverizes the soft rock which is then carried up by the drilling mud. Mitchell[7] has kept time foot by foot, while coring. As long as the rate per foot diminishes, coring operations are continued; but as soon as the rate accelerates appreciably, the coring is stopped, the core extracted, and operations resumed with the emptied barrel. This method has been responsible for practically full recovery of both the hard and very soft layers, even though alternating in occurrence. And if we are to continue to make laboratory tests for permeability, and analyses of saturation to estimate reserves, the first matter of importance is to recover all the producing formation.

REPLACEMENT OF DULL BITS

The geologist at the well who knows the approximate stratigraphic

[7] J. G. Mitchell, Pure Oil Company, Olney, Illinois, oral communication.

section to be encountered ahead of the progressive drilling depth of the hole is equipped to recommend the proper times to make round-trips to change bits, upon analyzing drilling-time data. As previously mentioned, the criterion of the dulling of the bit is the more gradual retardation of the rate of drilling. If the bit has become very dull but the interval to a formation change is estimated to be small, he may choose to continue drilling until the change is reached. If a reasonably long interval of hard formation is expected he may recommend a round-trip immediately, and thereby save many hours of time running on the dull bit. Such information has an appreciable economic value to the drilling company, and can be used to show a profit of several hundred dollars per well.

Since the dulling action takes place rather gradually, and is related to the lithologic character of the section being drilled, this factor does not need to confuse the one who is interpreting drilling-time data in terms of geologic changes, and does not lessen the value of foot-by-foot time records. The specific time is very much affected and is one of the reasons why specific time does not commonly correlate from well to well, inasmuch as the depths where bits are changed may not correspond.

SAMPLE LAG

The time interval for cuttings to travel from the bottom of the hole to the surface has a direct relation to depth. Hayward[8] has found that the time closely approximates the results of calculating the number of strokes of the mud pumps needed to displace the fluid in the hole divided by the strokes per minute. The lag in terms of finding the depth from which a given sample was penetrated by the drill can be determined approximately by referring the hour and minute the sample is caught to the hour and minute log of the drilling progress. However, the lag can be corrected at the horizons of the formation changes by correlating these with positions of acute acceleration and retardation recorded in drilling time.

Sample lag has not been corrected in the majority of sample logs of rotary wells. In other words the lag is assumed to be practically a constant and where operations are all with rotary tools, the relative structural differences are measurable. Electrical logs have come into prominent use to correct such lag at horizons where casing seats are chosen, or where producing zones are tested or casing is perforated. Drilling time will confirm the electrical logs.

[8] J. T. Hayward, oral communication.

TYPICAL WELL CASES

Maddox (3) published the logs of two wells in the Moore field, Cleveland County, Oklahoma, and illustrated the possibilities of the drilling-time method. He admitted that some improvement was needed to satisfy all the requirements for the geologist on the well to know precisely what formation was being drilled at all times. Others listed at the end of the paper have likewise indicated ways and means of applying time data to geological conditions, and especially to producing zones.

The most comprehensive discussion on completion practices in the writer's opinion is that by David (1) concerning the Goldsmith pool, Ector County, Texas. The seven well cases are graphically illustrated and described. The interpretation of drilling time per foot is correlated with porosity percentages from core analyses; the time per foot of the bracket 3–6 minutes signifies 5–10 per cent porosity, of the bracket 1–3 minutes signifies 10–20 per cent porosity, concerning the producing dolomite. The initial production per porous foot is reported to range from 35 to 50 barrels. Hard layers between the gas and oil zones are pointed out to be excellent casing seats to control the gas-oil ratios; the hard layers at the approximate contact of the oil and water zones are mentioned to be dependable stopping points for drilling in. The soft layers are very carefully logged so as to serve as a basis for acidizing, shooting, or remedial work on the well during the producing life period.

In Figure 1, three wells, A, B, and C, are illustrated as more or less random types. The three cases are presented to denote the advantages gained by keeping the true foot-by-foot record as given for well A. The average per foot for 5-foot intervals is used for well C, and for 10-foot intervals is used for well B. The lower portion of the log of well B contains the actual record for each foot, drawn in the dotted line.

Well A is a producer in a typical western Kansas field where oil saturation is found in the Lansing-Kansas City groups as well as in the Arbuckle limestone beneath. Where the saturation is of commercial importance the time per foot rarely exceeds 5 minutes and averages 3 or 4 minutes. In the depth interval between 3,200 and 3,240 feet the drilling rate is retarded obviously by the bit becoming dull. At 3,272 feet the fresh bit accelerated the drilling rate from 20 minutes to 7 minutes per foot where the formation drilled was the same in lithology. Forty feet was drilled with the bit very dull and represents a net loss in time to the drilling contractor of 8 hours and 40 minutes.

Well B is located at Oklahoma City. It had no saturation although

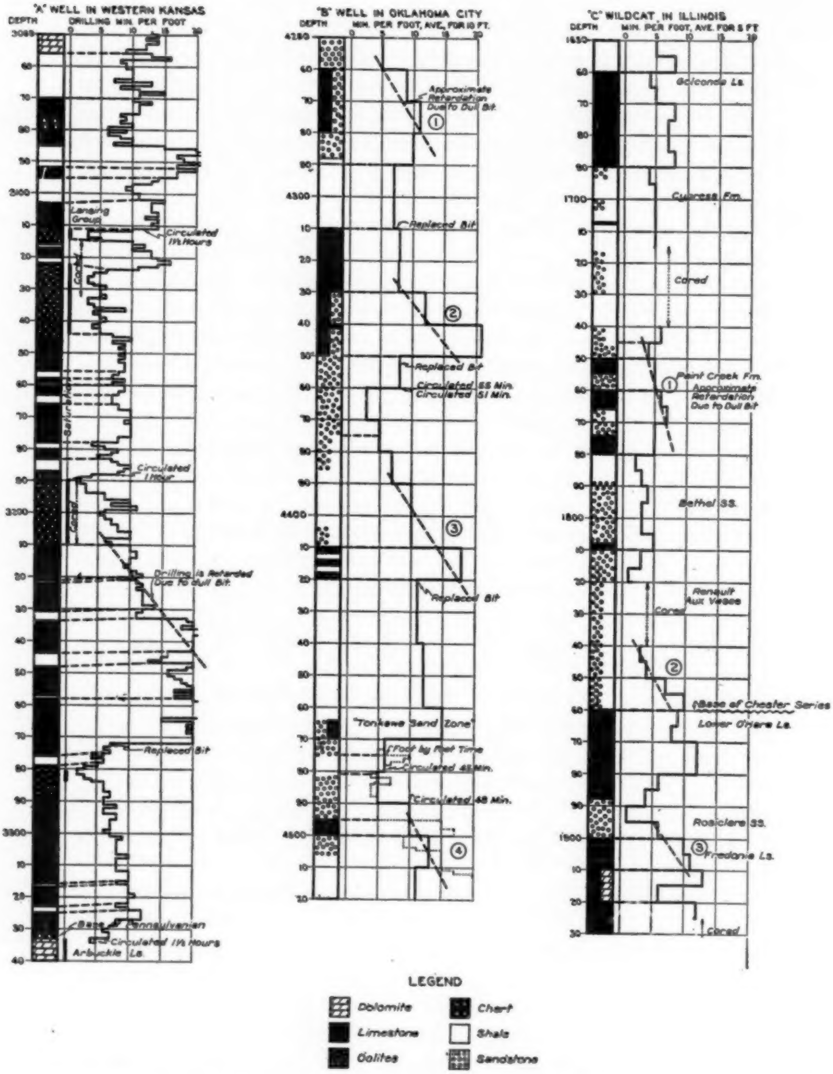

FIG. 1.—Conventional drilling-time logs of parts of three wells: "A" in western Kansas, "B" in Oklahoma City, and "C" in central Illinois. Well "A" has time recorded foot by foot, well "B" has time per foot averaged for 10 feet except foot-by-foot time given at very bottom, well "C" has time per foot averaged for 5 feet. Vertical scale is in feet; time scale is in minutes per foot drilled. Positions where bit is dulling are indicated.

the sand from 4,360 to 4,370 feet was soft enough to signify possibility of fluids and therefore samples were circulated to determine whether oil saturation was present. The dulling of the bits at the positions labelled 1, 2, 3, and 4 is rather obvious. In this case the bit replacements were made in logical manner. Below the depth of 4,470 feet the foot-by-foot record is particularly interesting in the manner whereby the details of the tops and bases of shale, sandstone, and limestone layers are delimited.

Well C is a wildcat dry hole in central Illinois. In this case the foot-by-foot time was recorded originally, but unfortunately only the average for 5-foot intervals was preserved. Schlumberger records were made, and the two methods checked nicely. Of course the micro-lithology was determined and interpreted along with drilling-time data at the well. In the depth interval between 1,790 and 1,820 feet, medium porosity was indicated by drilling time; and water saturation was shown on the electrical log. The same was likewise true for the interval, 1,890–1,900 feet. The dulling of the bits is not as obviously depicted in this well record as in wells A and B; however, the gradual retardation at positions labelled 1, 2, and 3 surely denotes such occurrences.

In Figure 2, wells D, E, and F are illustrated on the geolograph chart form and are reproduced from original records. The scale is in units of hours and minutes instead of depth as drawn in Figure 1. The three wells are given on a single 12-hour form for convenience, while actually the experience of encountering as many porous zones in as few hours' drilling period is not very common. The acceleration or retardation of drilling rates is readily detected from such charts in terms of minutes per foot. The dulling of the bit is not indicated in the examples cited, but such occurrences can be analyzed from the data on the charts where the rate retards gradually.

Well D, located in the West Frederick field, Tillman County, Oklahoma, was chosen for an illustration of the record where porosity was encountered in a limestone zone, part of the Canyon series of the Pennsylvanian. Above the depth of 3,260 feet the rate is 1 foot in 7 or 8 minutes; at 3,260–3,263 feet the rate increases to 1 foot in 5 minutes, and below 3,263 feet the rate is 1 foot in 3 to 4 minutes. The porous zone was confirmed in the electrical log. The tools were raised off bottom and a sample was circulated at 3,265 feet, requiring 1 hour and 3 minutes. No saturation was found and drilling was continued.

Well E, located in the Oklahoma City field, serves as an example where a shale was drilled above the depth of 3,237 feet at a rate of 1 foot in 8 minutes. Between the depths of 3,237 and 3,248 feet, a soft

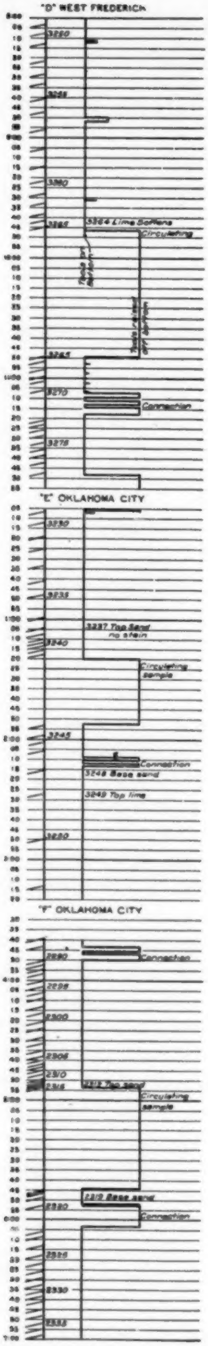

FIG. 2.—Drilling-time logs as recorded on geolograph chart, for parts of three wells: "D" in West Frederick field, southwestern Oklahoma; "E" and "F" in Oklahoma City. Chart heading is omitted, also bottom of chart is abbreviated which normally extends to 8:00 o'clock to cover 12-hour period. Time scale is in minutes, each unit being 5 minutes. Column at left gives time per foot, with depths given each 5 feet. Column at right denotes position of tools while drilling with line nearer time column, and position of tools when raised off bottom with line extended to right-hand direction. Notes explain shut-down occurrences.

sandstone was drilled at a rate of 1 foot in 2 to 3 minutes. Below the depth of 3,249 feet the rate decreased to 1 foot in 23–24 minutes, while drilling limestone. At 3,243 feet samples were circulated, no saturation was found, and drilling was resumed.

Well F, also located in the Oklahoma City field, exemplifies rapid rates of drilling progress at shallow depths. The rate above the depth of 2,305 feet is 1 foot in 3–4 minutes while drilling in shale. From 2,305 to 2,318 feet the rate accelerates to 1 or 2 minutes per foot, and represents a bed of porous sandstone. Samples were circulated at 2,315 feet, no saturation was found, and drilling was resumed. The rate below 2,318 feet is approximately the same as shown above 2,305 feet.

In each well mentioned the problem arose as to the advisability of coring. The drilling was stopped in each instance to examine the sample; had saturation been found coring could have been commenced in good position to make full use of it for studies of permeability and porosity. There have been many operations conducted where cores were taken of shale, after the sandstone had been completely penetrated, but no porous bed should be left without obtaining a circulated sample when the foot-by-foot drilling time is being watched at the well.

CONCLUSION

This discussion is submitted as an account of progress in recognition of the work of many field men who are responsible for making the rotary method of drilling satisfy requirements of high geological standards, and who are keeping pace with advancements in engineering fields. Detailed knowledge of subsurface stratigraphy should assist the office geologist to gain fuller comprehension of sedimentation and in turn stimulate exploration procedure.

PART II. DETERMINATION OF DATA

(BY P. B. NICHOLS)

ABSTRACT

Recording drilling time manually has been fairly successful, but the method allows the human element to enter largely into the accuracy of the data. The information has been restricted chiefly to the depths where production is expected, and of course has not been kept for most rotary operations.

The geolograph is an instrument which automatically records the rate of penetration, foot by foot, along with such related information as time out for repairs, round trips, *et cetera*. A diagram of the hook-up illustrates the manner in which the motion of the tools is recorded. A chart form depicts the typical drilling changes in rates of penetration together with the information as to when the tools are on bottom, when drill-pipe connections are made, samples circulated, *et cetera*.

The geolograph was conceived by the writer and developed in coöperation with the engineering department of the Indian Territory Illuminating Oil Company. Its success

has led to use as standard equipment on all this company's operations. The instrument is recommended as a geologist's tool as the record is subject to gross misinterpretation if studied apart from well samples and knowledge of geology of the areas involved.

The use of drilling time as a basis for the determination of a stratigraphic change is probably as old as the first rotary driller's log. Certain contrasting contacts such as shale with friable sand or dense limestone with porous lime are perfectly obvious to anyone on the rig floor. Nevertheless the rotary driller's log has always been of little or no value to the geologist and this may be one of the reasons why the importance of drilling time has so long been overlooked. The driller's responsibility is to make hole, to protect the hole already drilled and to keep up his equipment. When he sits down at the end of the tour to make out his report it is not surprising that the details are lost in 100 feet of "shale with streaks of sand and lime."

One of the first constructive efforts to utilize drilling time in correlation was that made in 1937 by Maddox (3) on two wells in the Moore pool, Cleveland County, Oklahoma. Several articles have appeared on the subject and the value of a detailed drilling-time record has been proved from the Gulf to Kansas and from California to Illinois.

RECORDING DRILLING TIME MANUALLY

The usual method of obtaining the drilling time is to stripe the "Kelly" with tool-joint lubricant at equi-spaced intervals of from 1 to 5 feet, or even 10 feet, according to the accuracy desired. As each successive mark reaches the rotary table the time and depth and elapsed time for drilling that interval are recorded. This information may be recorded by the geologist or engineer in charge of the operation but more often it is kept by one of the floormen under the direction of the driller.

The human element enters largely into the accuracy of this method. Rates of penetration as high as a foot a minute have been recorded at depths where shallow production might be expected. The contractor makes the most money per foot at the top of the hole and it is expecting too much of the floormen to make an accurate foot-by-foot drilling-time record when the driller is "pipe lining," or "stomping it down" through the upper formations.

The geologist also has his troubles when drilling is rapid. The lag or amount of time it takes a sample to reach the surface from bottom is a variable factor which increases with depth. In order to make accurate determinations at critical points it is customary to stop drilling and circulate samples from bottom or core the top of objective hori-

zons when changes in the character of the formation being drilled are indicated by a variation in the rate of penetration.

In a number of instances where no attempt was made to correct the log by circulating or coring, the sample log shows a lag ranging from 10 to 12 feet at depths ranging from 3,400 to 4,000 feet as compared with the drilling-time log. In one particular instance a perforation at the top of the sand by uncorrected sample log would actually have been in shale one foot below the base of the sand by the time log.

RECORDING DRILLING TIME MECHANICALLY

A recent innovation in the manner of obtaining the drilling time is the use of an instrument known as the geolograph. This device automatically records the rate of penetration with such related information as time out for circulating, for repairs, round trips, *et cetera* (Fig. 3).

In operation a flexible wire line is made fast to the "goose neck" of the rotary swivel, passed through a sheave about 50 feet above the derrick floor, thence down through the geolograph, and back over a second pulley in the derrick. A weight is fastened to this end of the line which moves freely in a guide composed of two joints of tubing fastened to the side of the derrick. In this manner the wire line actuated by the movement of the drill pipe and kept taut at all times by the weight, transmits the amount and direction of motion as it feeds through the machine in the various drilling operations.

Operation of the machine may be described briefly as follows. At any vertical movement of the drill pipe the line feeds into the device, passing around a wheel fitted with cams which contact a recording pen at one-foot intervals. As the chart is rotated by the clock this pen is recording a continuous vertical line until contact with a cam throws it out of line making a short horizontal line. The distance between any two of these lines represents the elapsed time required for drilling that foot of formation. Figure 2 shows some typical drilling-time breaks as recorded by this instrument.

Directly above and in sliding contact with the edge of the wheel described, is suspended in pendulum fashion, a common magnet. Free to swing in an arc, this magnet is responsive to the direction of motion of the wheel. An upper extension of this magnet carries a second pen which records these movements in the drilling operations column of the chart (Fig. 2).

When drilling is in progress, the direction of rotation being always the same, the pen records at the left of the column, but as soon as the bit is raised from bottom the reversal of direction causes the pen to

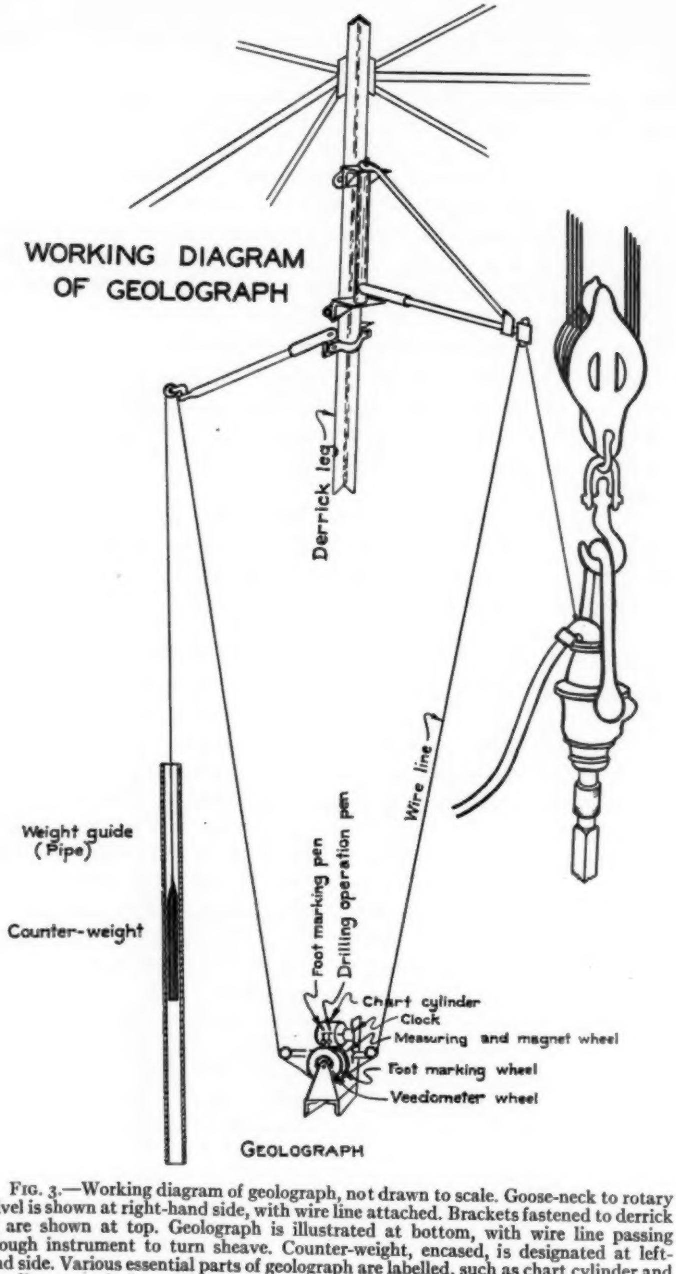

FIG. 3.—Working diagram of geolograph, not drawn to scale. Goose-neck to rotary swivel is shown at right-hand side, with wire line attached. Brackets fastened to derrick leg are shown at top. Geolograph is illustrated at bottom, with wire line passing through instrument to turn sheave. Counter-weight, encased, is designated at left-hand side. Various essential parts of geolograph are labelled, such as chart cylinder and recording pens, clock, and three wheels.

move to the right registering in that position until downward movement of the bit carries it back to the normal drilling position. In this manner the time required for "round trips," "circulating for samples," "repairs," *et cetera* in relation to each other and to the amount and depth of hole drilled is recorded without "fear or favor."

The margin at the right of the chart is used for explanatory notes. A few abbreviations in this column relative to the operation taking place or cause of the down time provides a very valuable record for future reference both to the operator and the contractor.

Another feature of the machine is the inclusion of a counter which is geared to the shaft of the measuring wheel and from which the total depth may be read directly at all times.

This is proving helpful in eliminating depth corrections. Failure to record a joint of pipe in the "tally" as well as mathematical errors are revealed by a discrepancy between the pipe book and the counter in the geolograph.

A clutch is provided by means of which the measuring wheel may be thrown out of driving relation with the cams which actuate the pen recording the drilling speed. This may be used when an operation such as reaming is in progress, which, if recorded, might be misinterpreted as rapid drilling. Use of the clutch does not affect the drilling-operations record.

The geolograph is generally installed in the geologist's sample shack placed a short distance from the derrick, although it has also been used in the corner of the derrick adjacent to the driller. Usual procedure is to rig up the machine while waiting, after cementing the surface pipe. The machine does not interfere in the drilling operation and it need not be disconnected until drilling has been completed.

The geolograph was conceived by the writer and developed in coöperation with the engineering department of the Indian Territory Illuminating Oil Company. It was first used in the Oklahoma City field in December, 1937. Success of this device has led to its adoption as standard equipment on all of this company's drilling operations. Only six machines have been constructed to date and their use has been confined to the Mid-Continent area. However, it is reasonable to assume that it will prove to be of value wherever the drilling-time method has been used successfully.

Accuracy of the geolograph in indicating points of stratigraphic change has been checked by coring and electrical logging. The foot-by-foot record obtained while coring is a valuable index to the porosity and permeability of the section cored and in case of failure to recover

a part or all of the core the geolograph record aids greatly in interpreting the character of the missing portion.

The geolograph was designed to overcome the existing problem of lag in rotary samples and it accomplishes this purpose. It is not claimed to be a cure-all and the record it makes is liable to gross misinterpretation if studied apart from the well samples and general stratigraphy and geology of the area involved.

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1. DAVID, MAX, "Use of Drilling Time in Determining Completion Practices—Goldsmith Pool," *Oil and Gas Journal* (March 31, 1938), p. 69; *Oil Weekly* (April 4, 1938), p. 39.

2. GALIAKOV, P., "A Study of Drilling Speeds Used in Russia," *Petroleum Engineer* (December, 1930), p. 77.

3. MADDOX, G. C., "Results of Logging Two Wells According to Drilling Speeds," *Oil and Gas Journal* (July 1, 1937), p. 36.

4. MILLS, BRAD, "Speed and Weight When Correctly Applied Has Definite Relationship with Drilling Footage," *Oil Weekly* (July 22, 1935), p. 25.

5. SANDERS, T. P., "Drilling Time Curves for Analyzing Pay Strata," *Oil and Gas Journal* (January 21, 1937), p. 43.

6. SIMONS, HARRY, "Time Records Aid in Drilling Program," *Oil and Gas Journal* (December 8, 1938), p. 56.

7. SWIFT, F. W., "Graphic Records of Drilling Time Have Many Valuable Features," *Oil Weekly* (March 12, 1934), p. 14.

8. WEBER, GEORGE, "Time Drilling Used Advantageously in Cotton Valley Development," *Oil and Gas Journal* (July 7, 1938), p. 38.

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VOL. 23, NO. 12 (DECEMBER, 1939), PP. 1835-1852, 6 FIGS.

GEOLOGICAL NOTES

HACKBERRY FORAMINIFERAL ZONATION AT STARKS FIELD, CALCASIEU PARISH, LOUISIANA[1]

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Houston, Texas

Since J. B. Garrett's[3] paper on the Hackberry assemblage was published there has been increasing recognition given to this foraminiferal fauna which occupies a stratigraphic position in the downdip Gulf Coast Tertiary below the zone of *Marginulina mexicana* var. *vaginata* Garrett and Ellis and above the top of the Vicksburg formation. It is significant of the importance of this foraminiferal assemblage that it has been found both on the flanks of piercement-type salt domes and also on deeply buried salt-dome structures of the Gulf Coast of Texas and Louisiana. Many commercial oil and gas zones occupy sandy phases below the dominantly marine shale wedge which contains the Hackberry fauna.

At the Starks field, Calcasieu Parish, Louisiana, a piercement-type salt dome, comparatively recent paleontologic research has revealed the presence of Hackberry foraminifera in the lower portions of many old well borings, previously identified with older designations. An ex-

Subdivisions of Hackberry Foraminifera—Starks Field, Calcasieu Parish, Louisiana

Textularia (distorted) sp.
**Cibicides hazzardi* Ellis[4]
Marginulina texana
**Cyclammina* sp.
Very large foraminifera
Clavulina sp.
Textularia cf. *dentimarginata*
Bolivina byramensis
**Bolivina mexicana* var.
(*Uvigerina stephensoni*)
Gyroidina scalata
**Ammobaculites nummus*
Bulimina sculptilis

* Of these subdivisions, *Cibicides hazzardi* (new name for "*Cibicides americanus* var.," listed by Garrett, *op. cit.*, p. 311), *Cyclammina* sp., *Bolivina mexicana* var., and *Ammobaculites nummus* are the most consistent horizon markers which can be used elsewhere. Both J. B. Garrett and A. D. Ellis, Jr., are in agreement on this *Cibicides hazzardi* designation (personal communication).

[1] Manuscript received, October 17, 1939.

[2] Consulting geologist and paleontologist.

[3] J. B. Garrett, "The Hackberry Assemblage—An Interesting Foraminiferal Fauna of Post-Vicksburg Age from Deep Wells in the Gulf Coast," *Jour. Paleontology*, Vol. 12, No. 4 (July, 1938), pp. 309–17, 2 figs., Pl. 40.

[4] A. D. Ellis, Jr., "Significant Foraminifera from the Chickasawhay Beds of Wayne County, Mississippi," *Jour. Paleontology*, Vol. 13, No. 4 (July, 1939), pp. 424–25.

ceptional opportunity was available to study several solidly cored well sections and as a result it was found possible paleontologically to subdivide the Hackberry into many small local horizons on the basis of their first occurrences. This research was done for the Skelly Oil Company under the direction of Joseph E. Morero, Lon D. Cartwright, Jr., and F. W. Mueller on flank tests of the Skelly Oil Company, the Union Sulphur Company, and other scattered well borings.

These Hackberry horizons were found at varying depths and intervals on the flanks of the Starks uplift between 3,700 and 6,600 feet. Similar horizons were found in Garrett's[5] original Hackberry check list at depths ranging from 7,407 to 7,695 feet.

Comparatively little is known at present concerning the geographic and geologic extent of the marine wedge containing the Hackberry foraminiferal fauna. The top of sandy phases which contain oil and gas lies almost immediately below the *Bulimina sculptilis* level in some deep-seated salt-dome structures, or where this horizon is absent, within 200 feet below the *Ammobaculites nummus* level. Examples of more recent Hackberry oil discoveries include South China, Jefferson County, Texas, and Woodlawn, Jefferson Davis Parish, Louisiana, both being deep domal structures.

[5] J. B. Garrett, *op. cit.*, p. 311.

PRESENT STATUS OF ST. PETER PROBLEM IN KENTUCKY[1]

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Lexington, Kentucky

The problem of the St. Peter sandstone in Kentucky has received a good deal of attention recently as interest has grown in deeper drilling for oil. Considerable work has been done on this problem in the last few years, but there is a great deal of disagreement in the results of the various investigators. It is the purpose of this paper to review briefly the conclusions published recently and to indicate their principal points of disagreement, and also to present the information up to date as furnished by well samples not available to earlier investigators.

Reid P. Meacham,[3] in his "Stratigraphic Analysis of Some Deep Well Records in Kentucky," indicated that the St. Peter is present at

[1] Read before the Appalachian Geological Society at Ashland, Kentucky, May 8, 1939. Manuscript received, October 23, 1939.

[2] Department of Mines and Minerals, Box 680.

[3] Reid P. Meacham, "A Stratigraphic Analysis of Some Deep Wells in Kentucky," *Kentucky Mineral and Topographic Survey*, Ser. VII, Bull. 2 (1933).

Frankfort, Franklin County, in northern Kentucky in Gallatin and Harrison counties, and on the east in Madison and Estill counties. He also points out a decided unconformity at the close of St. Peter time on the west side of the Cincinnati arch based on his identification of the bentonite ("pencil cave" of the driller) on upper Cotter. These determinations were made by the use of insoluble residues only, whereas if both the insoluble residues and the original samples are used the sequence is normal with bentonite at the top of the Tyrone, followed by about 600 feet of limestone and dolomite to the thin green shale marking the horizon of the St. Peter.

W. R. Jillson,[4] in his "Saint Peter Sandstone in Kentucky," recognized Meacham's unconformity, and indicated four elliptical areas of St. Peter in Kentucky, as follows: northern Kentucky, the Bluegrass, the eastern flank of the Cincinnati arch, and in southern Kentucky in Wayne and Clinton counties. Recent examination of well samples from these two counties shows that the St. Peter is not present and the porous zone so identified is really in the upper Knox dolomite. This interpretation agrees with that suggested by Kendall Born for Tennessee.[5]

Norval Ballard[6] published an article on the "Stratigraphy and Structural History of East-Central United States," in which he did not recognize Meacham's unconformity in a series of stratigraphic sections through Kentucky. He made the statement that he "believes that the St. Peter as a sandstone is probably absent in Eastern Michigan, Eastern Indiana, Ohio, Kentucky, and Tennessee." Fanny Carter Edson[7] reviewed Jillson's book on the St. Peter and agreed with Ballard about the absence of the sand in Kentucky.

C. L. Dake[8] shows by chart the St. Peter extending well up on the west flank of the Cincinnati arch and questionably across the arch and into eastern Kentucky.

Thus the problem stands in the literature at the present time. However, since these papers were published, a number of wells have been drilled through the St. Peter in Kentucky, from which samples were saved and studied in our laboratory. The locations of these wells and whether or not they showed the sand are shown in Figure 1.

[4] Willard Rouse Jillson, *The Saint Peter Sandstone in Kentucky* (1938).

[5] Kendall Born, correspondence with the writer.

[6] Norval Ballard, "Stratigraphy and Structural History of East-Central United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 11 (November, 1938), pp. 1519–59.

[7] Fanny Carter Edson, review of "The Saint Peter Sandstone in Kentucky," by W. R. Jillson, *ibid.*, Vol. 23, No. 1 (January, 1939), p. 107.

[8] Charles Laurence Dake, "The Problem of the St. Peter Sandstone," *Bull. School of Mines and Metallurgy, University of Missouri*, Vol. 6, No. 1 (1921).

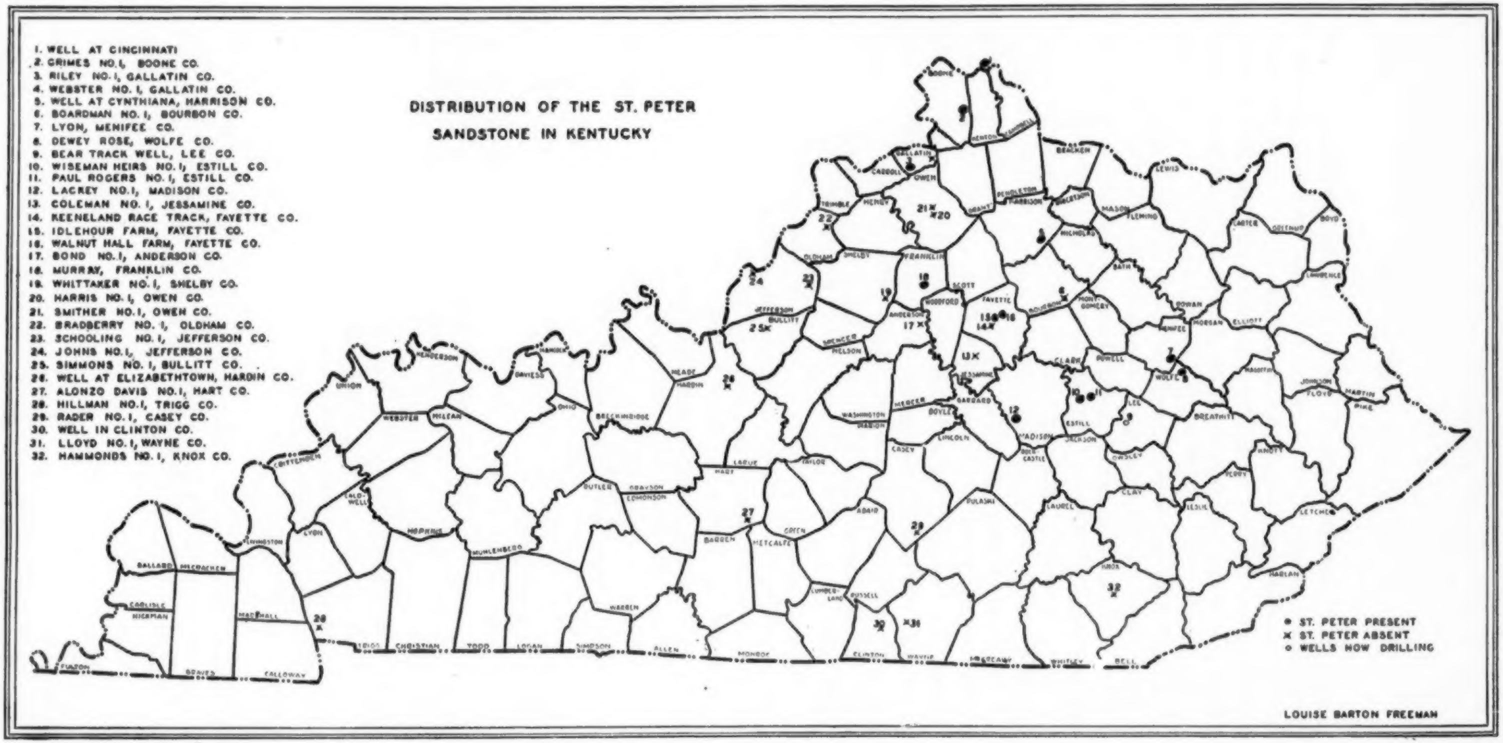
DISTRIBUTION OF THE ST. PETER
SANDSTONE IN KENTUCKY
1. WELL AT CINCINNATI
2. GRIMES NO. 1, BOONE CO.
3. RILEY NO. 1, GALLATIN CO.
4. WEBSTER NO. 1, GALLATIN CO.
5. WELL AT CYNTHIANA, HARRISON CO.
6. BOARDMAN NO. 1, BOURBON CO.
7. LYON, MENIFEE CO.
8. DEWEY ROSE, WOLFE CO.
9. BEAR TRACK WELL, LEE CO.
10. WISEMAN HEIRS NO. 1, ESTILL CO.
11. PAUL ROGERS NO. 1, ESTILL CO.
12. LACREY NO. 1, MADISON CO.
13. COLEMAN NO. 1, JESSAMINE CO.
14. KEENELAND RACE TRACK, FAYETTE CO.
15. IDLEHOUR FARM, FAYETTE CO.
16. WALNUT HALL FARM, FAYETTE CO.
17. BOND NO. 1, ANDERSON CO.
18. MURRAY, FRANKLIN CO.
19. WHITTAKER NO. 1, SHELBY CO.
20. HARRIS NO. 1, OWEN CO.
21. SMITHER NO. 1, OWEN CO.
22. BRADBERRY NO. 1, OLDHAM CO.
23. SCHOOLING NO. 1, JEFFERSON CO.
24. JOHNS NO. 1, JEFFERSON CO.
25. SIMMONS NO. 1, BULLITT CO.
26. WELL AT ELIZABETHTOWN, HARDIN CO.
27. ALONZO DAVIS NO. 1, HART CO.
28. HILLMAN NO. 1, TRIGG CO.
29. RADER NO. 1, CASEY CO.
30. WELL IN CLINTON CO.
31. LLOYD NO. 1, WAYNE CO.
32. HAMMONDS NO. 1, KNOX CO.
● ST. PETER PRESENT
✕ ST. PETER ABSENT
○ WELLS NOW DRILLING
LOUISE BARTON FREEMAN

FIG. 1

TYPICAL SECTION BELOW TRENTON LIMESTONE

TYRONE (Birdseye limestone of Linney), dense gray, dove-or cream-colored, breaks with conchoidal fracture, small pockets of calcite crystals. Well developed bentonite occurs 5–10 feet below top. Very persistent and easily recognized zone

OREGON, magnesian limestone with streaks of finely crystalline dolomite through dense limestone of Tyrone type

CAMP NELSON, magnesian limestone with bands of more argillaceous greenish limestone; a few birdseye beds, cream to light tan in color; lower part more dolomitic, dolomite being very finely crystalline and soft, lithologically much like Joachim of Missouri. Base of this may enclose a little sand, grains being small and angular to rounded

ST. PETER, clean, white sandstone, with large well rounded and frosted grains, surface texture suggesting eolian origin, although Dake points out that it was redeposited in marine waters with associated marine fauna in Missouri. Remarkably pure sand and may contain as much as 98 per cent silica. Known as "Wilcox" by drillers in Oklahoma and Texas where it has been big producer

Green shale, thin, bentonitic, may enclose large rounded and frosted sand grains

Dolomite, very finely crystalline, less calcareous than basal Camp Nelson dolomite; much white, translucent chert, in some places enclosing quartz grains, some chert finely disseminated leaving soft porous mass in residue

Dolomite, very coarsely crystalline, white to light tan, much chert some of which has been altered to tripoli. May contain sand lenses

The exact age relationships of the St. Peter have not been determined at the outcrop to the satisfaction of all students of Ordovician stratigraphy. Nevertheless, its position between the Knox dolomite and the Joachim (Camp Nelson in Kentucky section), whether this be Stones River or Black River in age, is generally accepted. There is a sandstone of the St. Peter type at this horizon in several wells in Kentucky.

In outcrop descriptions of the St. Peter in Missouri, Weller and St. Clair[9] mention a thin green shale associated with the sand. Samples from the Kentucky wells, in all places, whether a sand is present at this horizon or not, show a little green shale. In a few wells, for instance in the Boone and Hart counties wells, a clue to the origin of the shale is given, as here it is distinctly bentonitic with many fragments of coarse-grained bentonite showing large flakes of biotite. Thus, two bentonites are everywhere present and easily recognized in this section, one at the top of the Tyrone and the other at the top of the Knox. The interval between these two bentonites is fairly constant, indicating that the whole section of the Lowville-Stones River is present on the west flank of the arch in all the wells drilled to date, and that the unconformity described by Meacham does not exist. This 600-foot interval continues across the Cincinnati arch, but in north-central Kentucky in Gallatin and Boone counties it is less than 600 feet, and only 475 feet in a well at North Middletown, Bourbon County. The lessened interval is due to the thinning of the finely crystalline dolomites of the lower Camp Nelson. There is a corre-

[9] Stuart Weller and Stuart St. Clair, "Geology of Ste. Genevieve County, Missouri," *Missouri Bur. Geol. and Mines*, Vol. 22, Ser. 2 (1928), p. 97.

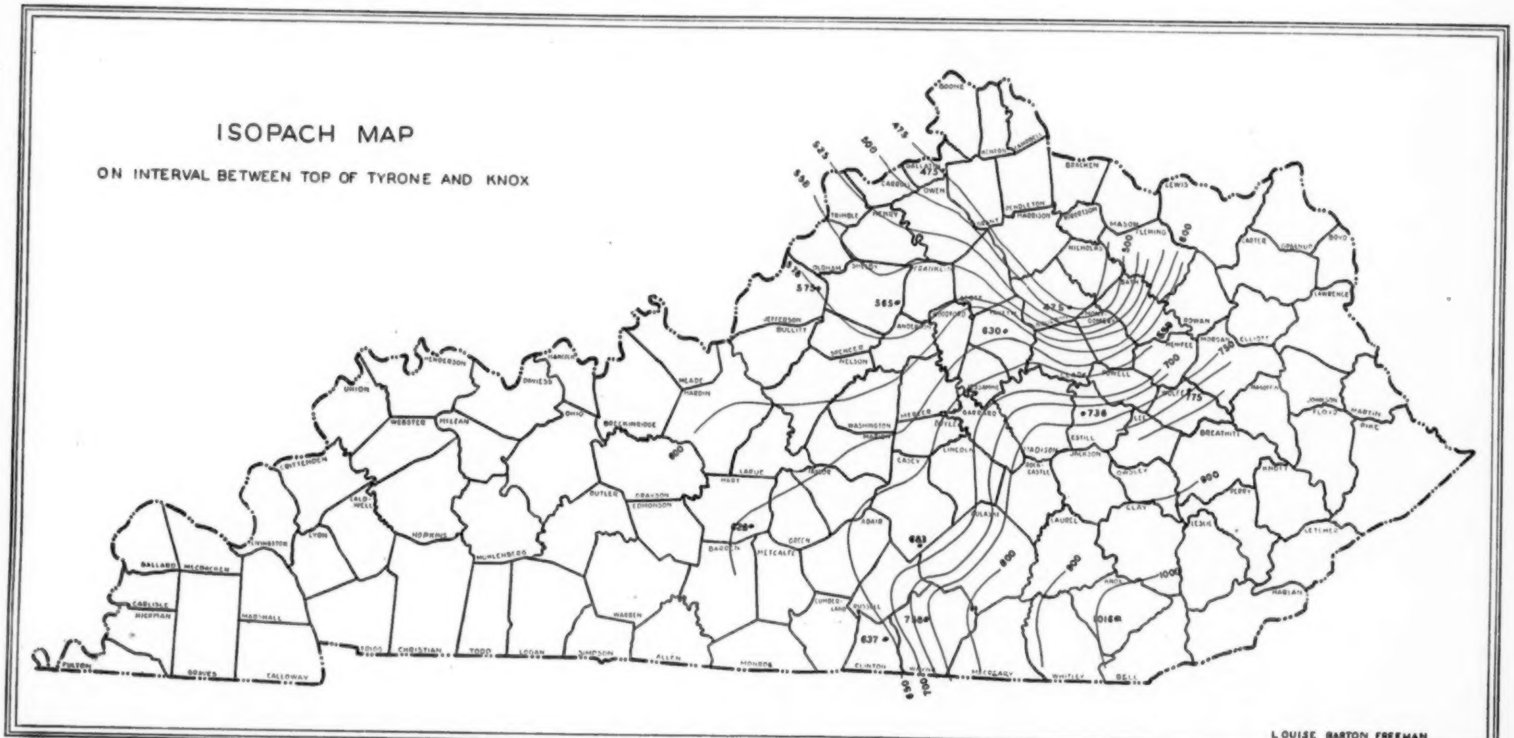
ISOPACH MAP
ON INTERVAL BETWEEN TOP OF TYRONE AND KNOX
LOUISE BARTON FREEMAN

FIG. 2

sponding thickening of this series toward the south as indicated in Figure 2.

As indicated in Figure 1, the St. Peter sandstone is present in none of the wells on the west side of the Cincinnati arch, nor is it present in the wells in Wayne and Clinton counties (Jillson's southern area). In Hart County there is a little sand, dolomite-cemented, at the St. Peter horizon, but the sand is rather fine with only rare, large, rounded and frosted grains, and probably is the sandy phase at the base of the Camp Nelson.

The occurrence of the sand on top of the arch is rather spotted. Thus it is present in two wells drilled in Fayette County and absent in a third. Water wells drilled on the Walnut Hall Farm and on the Idlehour Farm had St. Peter, but it was absent in one drilled at Keeneland Race Track. Neither is it present in a well being drilled near Nicholasville, Jessamine County. Meacham lists it in one well in Gallatin County. The samples he used are not available at this time, but those from a more recent well in the same county do not show the sand. It has been described in a well at Cincinnati and is present a few miles south in Boone County. The water well mentioned at North Middletown, Bourbon County, failed to get a sand at this horizon.

Contrary to what might be expected, the St. Peter is present in all the wells examined in this study on the east side of the arch. Its greatest thickness is in a well drilled on White Oak Creek in Estill County where there is 63 feet of sand, the upper 30 feet of which is calcareous and fine-grained and probably belongs in the lower Camp Nelson. However, there is 43 feet of coarse, loosely cemented, white sand, with the grains showing rounding and frosting and some secondary crystal growth. An old well drilled northeast of this well by the Wood Oil Company had 10 feet of sand at this horizon, and a recent well in Wolfe County had only 5 feet of more fine-grained though still rounded and frosted sand.

Two deep wells are being drilled now, one in Lee County, and the other in Knox. The Knox County well has penetrated the St. Peter zone but found no sand, so that in Lee County should give some important information regarding the southern extent of this sand body.

The underlying Knox cherty dolomite contains a few sand lenses where the sand is of the same type as the St. Peter, and the fact that in a few wells that have penetrated this it has been correlated with the St. Peter is a natural enough mistake. The Walnut Hall well in Fayette County showed the St. Peter and another sand similar but thinner about 100 feet below. The Bond well at Lawrenceburg, Ander-

son County, has no sand at the St. Peter horizon, but has a well developed sand containing fresh water 450 feet below the top of the Knox, and another sandy zone 100 feet below that. This well was drilled 2,000 feet below the top of the Knox and drilled dolomite all of the way. The occurrence of the fresh water at this horizon below the sulphur water commonly found in St. Peter wells, whether a sand is present or not, was exceptional. The dolomite at the contact with the overlying Camp Nelson or the St. Peter sand has sufficient porosity to contain water and in some places a little sulphur gas.

The problem of the St. Peter occurrence in Kentucky is by no means settled, nor will it be until there is available more information on its presence and on the underlying beds so that its exact relationships may be determined. A beginning was made in this direction by plotting the percentage of chert in each well below the St. Peter. Some horizons are much more siliceous than others, and it was found that there was a remarkable conformity in these charts. This picture, together with the almost invariably present green shale and the constant interval of the Lowville-Stones River, is in sharp contrast to the irregular occurrence of the St. Peter sandstone.

The pattern from the information at hand suggests an old St. Peter shore line extending across the Cincinnati arch at the northern tip of Kentucky, swinging south on the east flank and extending well up on the present crest of the Jessamine dome.

The following sample log is given as generally typical of the Ordovician section in Kentucky below the top of the Tyrone.

PARTIAL LOG OF WISEMAN HEIRS NO. 1, DRILLED BY PETROLEUM EXPLORATION AND SOUTH PENN OIL COMPANY, WHITE OAK CREEK, ESTILL COUNTY

Depth in Feet	
1,130–1,150	Limestone, brown, coarsely crystalline and some light, rather chalky, dense limestone; some finely crystalline gray-brown dolomite that is slightly argillaceous, leaving well developed dolocasts in clay residue; some blue-white almost transparent chert; some bentonite
1,160	Dense, brown, rather cherty limestone with some bentonite. Residue shows much brown chert, most of which is very finely mottled; a little banded chert some showing coating of fine quartz crystals; here and there fossil replacement in silica (one *Rhinidictya*); much bentonite
1,165	Limestone, brown, dense, hard with streaks of brown crystalline dolomite; some bentonite and a little dark brown chert
1,170	Limestone as above but with more blocky, light brown chert
1,180	Limestone, dense, hard, brown, with a few calcite facets
1,195	Limestone, dense, brown, and some shaly grayish limestone; more bentonite and some pyrite
1,215	Limestone, hard, dense, fine-grained, and some finely crystalline brown dolomite
1,220	Limestone, as above; more dolomite
1,235	Limestone, dense, light brown; and some crystalline dolomite, very slightly argillaceous with light clay material in residue
1,250	Limestone, cream-colored, dense, and some brown crystalline dolomite; very little translucent chert

1,260	Dolomite, finely crystalline, white to light tan
1,280	Limestone with some dolomite, darker brown than above
1,300	Limestone as above but more argillaceous, some dolomite
1,365	Limestone, dense, light brown, with some calcite facets; some brown crystalline dolomite with little disseminated clay
1,375	Same with some bentonite
1,390	Limestone, dense, brown, some showing leaching; some chert
1,455	Limestone, brown and white, dense, hard, a little of it chalky from leaching; some crystalline brown dolomite; very little replacement silica in residue
1,465	Dolomite, very finely crystalline, light brownish gray
1,480	Limestone, white lithographic, rare pyrite flecks included; a few fragments of blue-white translucent chert
1,485	Limestone, dense, slightly argillaceous
1,515	Limestone, dense, brown to white to pale green
1,535	Limestone, dull brown, dense, with a few fragments of crystalline brown dolomite
1,540	Limestone, darker in color, argillaceous in streaks
1,580	Limestone with dolomite increasing to 1,550 feet, then decreasing gradually
1,585	Limestone, slightly argillaceous, more fossiliferous than above
1,600	Limestone, clean brown, dense, lithographic
1,605	Limestone, more argillaceous, showing oil-stain
1,625	Limestone, brown, dense, lithographic
1,640	Limestone, more argillaceous, greenish, little crystalline
1,665	Limestone as above with some crystalline dolomite
1,670	Limestone, more crystalline and oil-stained, some argillaceous
1,680	Dolomite, very finely crystalline, light tan
1,695	Limestone, dense, hard, grayish brown, and some dolomite
1,725	Limestone, very finely crystalline to dense, some green argillaceous streaks
1,730	Dolomite, very finely crystalline, light-colored, Joachim type
1,740	Limestone, almost black, dense to argillaceous
1,785	Dolomite, finely crystalline, light-colored; very little argillaceous material
1,800	Dolomite as above but some argillaceous
1,805	Dolomite, fine-grained, some argillaceous, here and there fine sand
1,820	Dolomite with much sand included; rare rounded and frosted grains; most of sand is fine-grained and angular to rounded
1,830	Sandstone, dolomite-cemented; grains as above
1,873	Sandstone, grains large rounded and frosted, some showing secondary crystal growth
1,900	Dolomite, finely crystalline with a few included sand grains; considerable chert and green shale
1,910	Dolomite as above but less cherty
1,940	Dolomite, finely crystalline, much chert, some finely disseminated through dolomite, some dense and translucent
1,950	Dolomite with less chert and some rounded and frosted sand grains
1,955	Dolomite, creamy white, crystalline with much chert, some agatized and some appearing in residue as coarsely dolocastic fragments; a few rounded and frosted sand grains
1,960	Dolomite, coarsely crystalline and cherty; fragments show distinct rhombic crystals of dolomite cemented with white chert; dolocasts thin-walled, some tripoli
2,020	Dolomite as above and some finer-grained; less chert
2,025	Dolomite, browner and more tightly crystalline; little dolocastic chert and tripoli, some brown transparent chert; some rounded and frosted sand grains
2,030	Dolomite as above; some chert whiter and some bentonite
2,050	Dolomite as above but much more chert

PRODUCTIVE AREAS IN THE McCLOSKY OF WESTERN KENTUCKY[1]

DANIEL J. JONES[2]
Lexington, Kentucky

The oölitic beds of the Ste. Genevieve limestone known as the McClosky are productive in at least twelve different areas in the Western Kentucky Coal basin. At Birk City, in eastern Henderson and western Daviess counties, production from this "pay" covers several hundred acres and no doubt other locations will be drilled adjacent to this pool. In the remaining localities within the basin it remains to be proved whether the productive areas will cover many acres or not. Present indications point to the likelihood that most of these pools will either be small or decidedly spotted.

The intensive drilling that followed the discovery of the Birk City field has accounted for ten of the twelve areas. No doubt drilling during the next few months will develop other pools.

It is possible from the present development to draw either of two conclusions as to the value of this pay zone. To date, Birk City is the outstanding productive area. Few dry holes have been found within the main productive area. There is ample space and there should be many other pools comparable with, or better than, Birk City. On the other hand, when we consider that it is very unlikely that several of the spots where there are now one or more commercial wells will be extended much beyond their present limits, the picture is not as bright. The writer prefers to take the optimistic view and consider that the finding of such a number of rather widely scattered spots means that the Ste. Genevieve does contain large quantities of oil and will be an important oil producing formation.

The structure of the Birk City field is a series of roughly parallel, southwestwardly plunging anticlinal folds. The rate of dip is approximately 50 feet per mile. This type of deformation is common in the Western Kentucky Coal basin. The exact location south and east of the pool, as well as the importance of the Curdsville fault is yet an unknown factor.

A study of producing wells and dry holes in the Birk City area indicates that the accumulation of oil is related to the anticlinal folding. The production from the McClosky formation is due to a combination of two factors principally: (1) position on the structure, and

[1] Read before the Appalachian Geological Society at Ashland, Kentucky, May 8, 1939. Manuscript received, October 24, 1939.

[2] Kentucky State geologist, 146 Bassett Street.

(2) the development of a zone of large, loosely cemented oölites. Some of the tests on the downdip edges of the productive area have produced water, indicating a water drive.

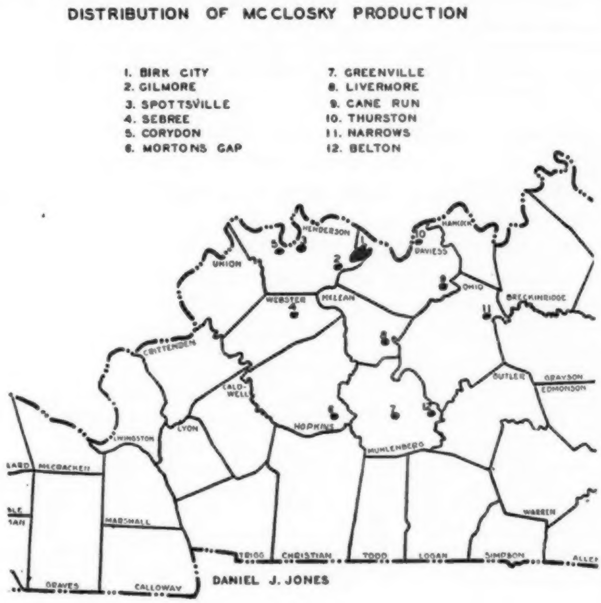

FIG. 1

Mrs. Freeman[3] makes the following observations as to stratigraphy and lithology.

The McClosky is encountered in this district about 100 feet below the base of the Cunningham. It is a zone of large, loosely cemented oölites, many of which are irregular in form due to the fact that small fossils form the nuclei. In many cases the fossils break free from the enclosing calcium carbonate and can be identified as the same forms making up the dwarfed fauna of the Salem. Two wells in McLean County showed the McClosky at 210 feet below the base of the Cunningham and one of these showed a similar zone about 50 feet below the first. Evidently the position of the McClosky within the Ste. Genevieve varies from place to place.

A study[4] of the lithology of the oölitic members of the Ste. Gene-

[3] D. J. Jones and Louise Barton Freeman, *Structure and Stratigraphy of the Birk City Oil Field*, published by the Kentucky Oil and Gas Association and the State Department of Mines and Minerals (September 1, 1938).

[4] Louise Barton Freeman, "The 'McClosky' Oil Horizon in Western Kentucky," *Kentucky Dept. Mines and Minerals*, Ser. VIII, Bull. III (1938).

vieve reveals that there are in many places two distinct types of oölites.

1. The most common type, and the one that is found consistently in outcrop as well as in well cuttings, is a small round, usually tightly cemented oölite averaging about .05 mm. in diameter.

2. The other type, less frequently encountered is much larger, ranging from .07 to .15 mm. These oölites are irregular in shape due to the fact that many have small fossils as nuclei.

In all samples studied which show these oölites the horizon has produced either oil or water, or has fairly high porosity. As might be expected the oölites show little cementing material and easily break free of the matrix.

The conclusions drawn by Mrs. Freeman[5] are as follows.

(1) The depth to the "McClosky" varies considerably over the Basin. To be certain, a test should be drilled until oil or water is encountered, or completely through the Ste. Genevieve series, 300 to 350 feet below the Cunningham interval.

(2) An occasional higher oölitic zone in the Ste. Genevieve may show a little oil. However, the combination of large fossiliferous oölites and overlying thin dark shales has been noted in every case where the porosity was sufficient for production.

(3) A number of wells drilled in Western Kentucky in the last few years supposed to have been McClosky tests did not reach the oölitic facies of the Ste. Genevieve which produces in the Birk City area.

Pipe-line runs from April to December, 1938, inclusive, totalled 731,752 barrels from the Birk City field. On January 1, 1939, the field had 103 oil wells producing from the McClosky, 3 oil wells producing from the Cunningham sand, and 2 gas wells, one of which is producing from the Hardinsburg, and the other from the Tar Springs. A total of 26 dry holes had been drilled.

George Ballentine's[6] conclusions in his report on the economic aspect of the Birk City pool are as follows.

The decline in production is rapid and will follow the trend of the McClosky in the Illinois pools.

It is estimated that a well with ten acre spacing and having an initial thirty days production of 3,000 barrels has ultimate reserves of about 15,000 barrels and will approximately pay out on $1.25 oil.

Serious consideration should be given to spacing before making a location in the Birk City Pool. The present information indicates that any part of the pool, developed on a spacing of five acres per well or less, will not as a whole return the investment.

[5] *Ibid.*

[6] George L. Ballentine, "Economic Study of Birk City Oil Pool in Henderson and Daviess Counties, Kentucky," *Kentucky Oil and Gas Assoc.* (September 1, 1938).

Production figures from the pool as a whole for the year 1938 confirm the conclusions of Ballentine. The good properties where spacing ranges from 11 to 15 acres per well will return profit to the operator. As usual, the town-lot spacing returns profit only to the promoter.

CINCINNATI ARCH AND FEATURES OF ITS DEVELOPMENT[1]

ARTHUR C. McFARLAN[2]
Lexington, Kentucky

The axis of the Cincinnati arch passes north by east through Tennessee and Kentucky, then splits in northern Kentucky and one limb passes on either side of the Michigan basin. Two domal structures are developed along the axis: (1) the Jessamine dome of central Kentucky, which is the region under consideration, and (2) the Nashville dome of central Tennessee. The oldest exposed rocks are the Camp Nelson (Stones River) beds, which crop out with maximum thickness in the Kentucky River gorge at Camp Nelson from which they take their name. However, the structure rises a little higher toward the south in Garrard County in the vicinity of Burdett Knob where it is cut by the Kentucky River fault zone.

Notes on the progressive development of the arch have appeared in the literature for many years, and in Schuchert and Dunbar's *Historical Geology* (1933) the development of the arch is given as having been initiated in the Ordovician. Two main periods in its building are commonly recognized: one in the pre-mid-Devonian and a second at the time of the Appalachian revolution. Wilson (1935) has discussed in some detail evidence of early uplift in the region of the Nashville dome.

Some points of interest involving earlier rocks include the following.

1. Mrs. Freeman (1939) has shown a more or less uniformly thick Stones River-Lowville sequence throughout central Kentucky.

2. The writer (1938) has shown evidence of a shallow east-west Trenton syncline through central Kentucky based on the relationships of the Lexington limestone to later Trenton rocks.

3. Evidence of an early "Cincinnati island" in central Kentucky is found in overlapping relationship of Perryville and basal Cynthiana (Trenton) (McFarlan, 1938) and Fulton (lower Eden) (McFarlan and Freeman, 1935).

[1] Manuscript received, October 27, 1939.

[2] University of Kentucky.

The significance of these features is open to question. They may represent minor upwarps which may have been only a few of many, and assume apparent significance only because of location in the region of Trenton and Eden outcrop. However, there does seem to be a contrast with the pre-Trenton. Instead of the uniformity of the Stones River-Lowville, the section becomes one of varying thicknesses, locally varying lithology and faunas, and one showing local unconformity and overlap. This condition is indicated through the

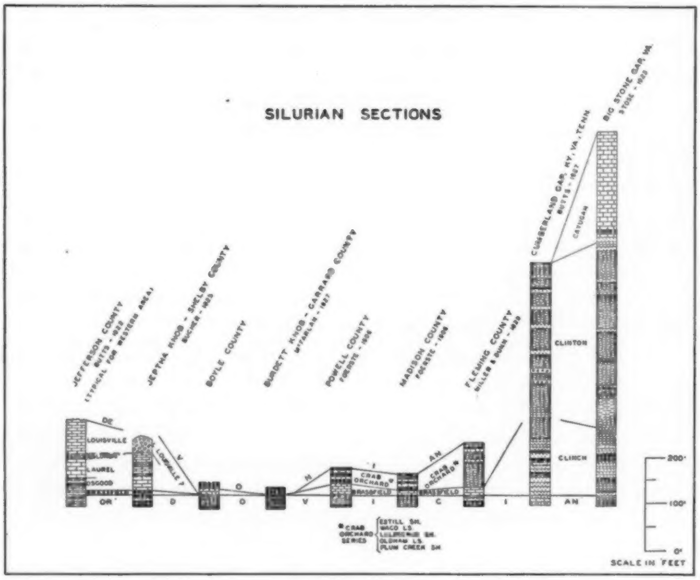

FIG. 1

later Ordovician and exposed part of the Silurian (Foerste, 1906, 1931, 1935) section.

The most striking unconformity of the Kentucky Paleozoic, except that of the Mississippian-Pennsylvanian contact, is the mid-Devonian overlap toward the axis of the arch. In the area of outcrop (Fig. 1) this involves an overlap of mid-Devonian limestone from mid-Silurian to Richmond and Maysville. Farther east under cover it has been shown to involve the Cayugan and Helderberg (Ballard, 1938). In Ohio and Tennessee, and as shown by drill records in western Kentucky (Freeman, 1939), the Black shale is the overlapping formation.

Though the arch indicated is comparable in extent with the present one, this early "island" condition was of no great height and did not last long, as indicated by the presence of the Boyle limestone (Hamilton), Ohio shale, and Waverly preserved in downfaulted blocks in the region of the crest of the Jessamine dome. This is best shown at Burdett Knob in Garrard County, where from topographic relationships it is inferred that the St. Louis was also formerly present. Outlying remnants of a former Pottsville cover far from the Pottsville escarpment fit into the same general picture.

A consideration of the "Eastern Kentucky geosyncline" has a bearing on the development of the arch. This structure is not of the order of magnitude or of the nature of a geosyncline (a progressively sinking trough in which a great thickness of sediment accumulates), but the term has been in use by the Kentucky Geological Survey for a great many years. It constitutes the southern end of the Pittsburgh basin, partly isolated from the rest by the Paint Creek uplift (Fig. 2).

Attention is called to the fact that this reversal of eastern dip, as drawn on the Fire Clay coal, is not reflected in the structure of the Black shale (State structural map). On the outcrop the Jessamine dome terminates on the east with the trough of the "Eastern Kentucky geosyncline." In the subsurface at the horizon of the Black shale (or below this) the regional structure is continued eastward to the Pine Mountain thrust. This lack of accordance between surface and subsurface structure is interpreted as due to progressive sinking east and southeast, particularly in the early Pennsylvanian, along the western flank of the Appalachian geosyncline. It is indicated in the tremendous increase in interval between the Fire Clay coal and the base of the Pottsville and older formations toward the southeast. The coal at the time of deposition represented a topographic, as well as stratigraphic, plane. The later forming of the "Eastern Kentucky geosyncline" as portrayed on the Fire Clay coal merely flattened the convexity of the Black shale structure developed by the progressive subsidence previously mentioned (Fig. 3). But prior to this final folding an eastern flank of the Jessamine dome was well developed as a result of this and earlier subsidence.

In considering the Pittsburgh basin, there is not indicated (in the Kentucky portion at least) a suggestion of progressive development; rather, the contrary. This basin is certainly a product of the Appalachian revolution. This is shown by the Pennsylvanian section, which, though of greater stratigraphic range (Pottsville-Conemaugh), is represented by a thickness of a few hundred as compared with a few thousand feet of Pottsville on the southeast outside the basin.

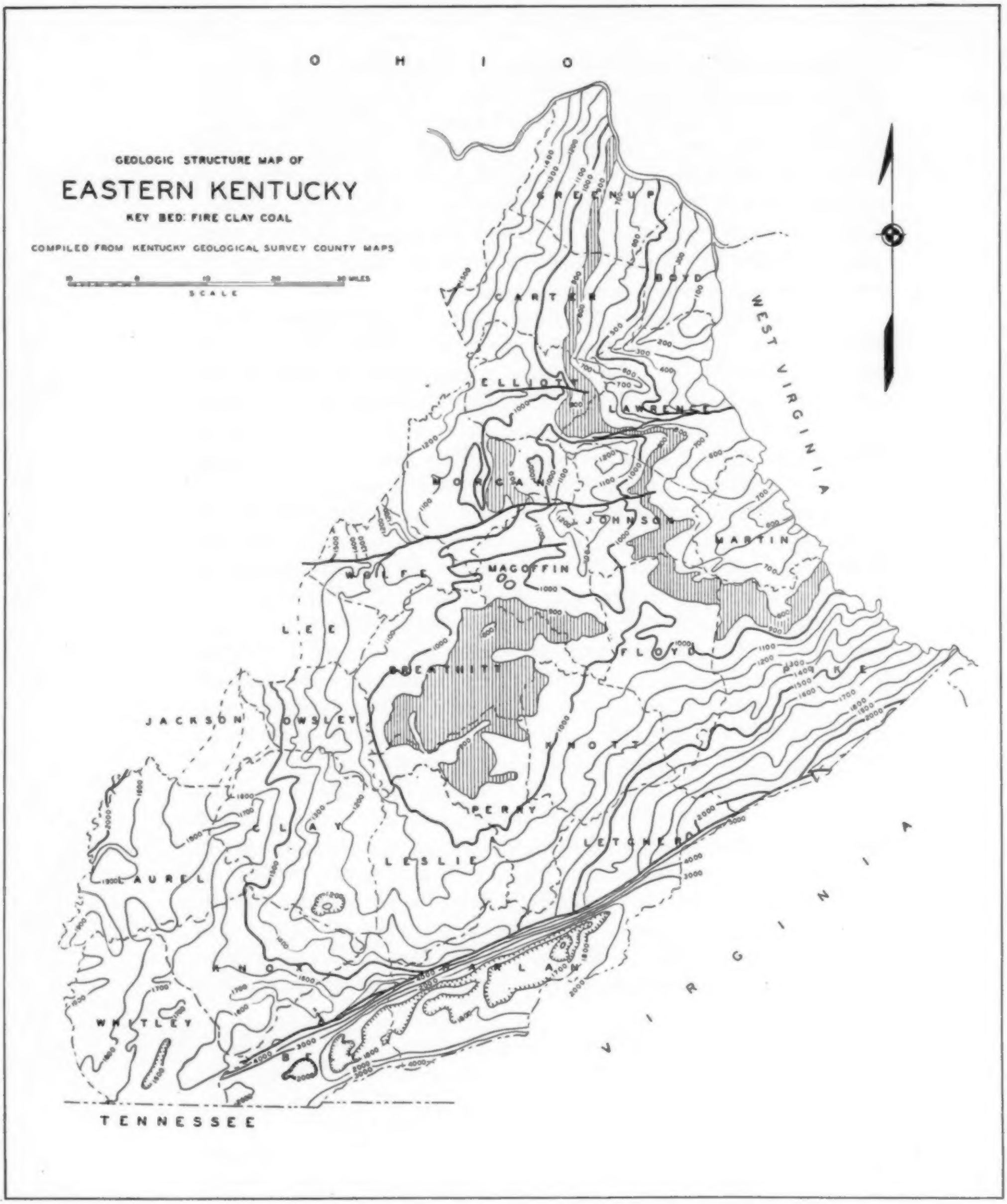
GEOLOGIC STRUCTURE MAP OF
EASTERN KENTUCKY
KEY BED: FIRE CLAY COAL
COMPILED FROM KENTUCKY GEOLOGICAL SURVEY COUNTY MAPS
SCALE
OHIO
WEST VIRGINIA
VIRGINIA
TENNESSEE
GREENUP
BOYD
CARTER
ELLIOTT
LAWRENCE
MORGAN
JOHNSON
MARTIN
WOLFE
MAGOFFIN
LEE
FLOYD
BREATHITT
JACKSON
OWSLEY
KNOTT
CLAY
PERRY
LESLIE
LETCHER
LAUREL
KNOX
HARLAN
WHITLEY

Fig. 2

This is a reversal from something corresponding with a condition of structural "high" to that of a structural "low."

Western Coal basin.—This is a local term covering that part of the Eastern Interior Coal basin which lies in northwestern Kentucky. Several writers have called attention to stratigraphic relationships suggesting a geosynclinal area in this region west of the arch, and have suggested that it is not co-extensive with the present outline of the Western Coal basin (Russell, 1932; J. M. Weller, 1936; Ballard, 1938; and Freeman, 1939).

In conclusion it is suggested that the concept of a progressively rising Jessamine dome (Cincinnati arch) may better be replaced by one

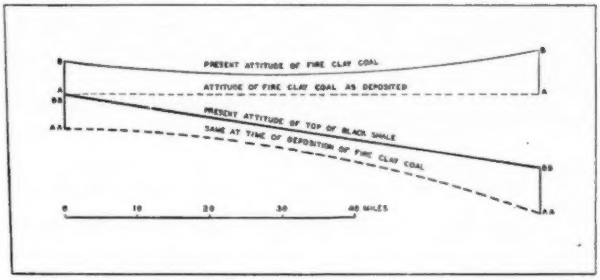

Fig. 3

in which the early history of the arch, and a phase responsible for a large part of the completed structure, was one in which the central area was more or less passive (neutral), never much above or much below sea-level, while on the east and (though not so well known) on the west were regions of active crustal sagging. This eastern region comprised the western flank of the well known Appalachian geosyncline and by this sagging much of the present eastern dip of the eastern flank of the arch was produced. It is suggested that the overlapping relationship of the mid- and late-Devonian was due to similar sagging, and on the east and west resulted in progressive retreat of the seas rather than central upwarp and truncation of the structure by erosion.

At the close of the Paleozoic as a part of the Appalachian revolution the Jessamine dome was reshaped, the Western Coal basin was shaped from a part of the western negative area, and at least the Kentucky part of the Pittsburgh basin formed from a region formerly structurally positive.

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 23, NO. 12 (DECEMBER, 1939), PP. 1853-1858

DISCUSSION

CABO BLANCO BEDS OF CENTRAL VENEZUELA[1]

L. KEHRER[2]
San Cristobal, Venezuela

With reference to the reply of M. Kamen Kaye[3] to the writer's discussion[4] of Kaye's article, "Geological Succession of Central Venezuela,"[5] there is mainly one point which deserves further explanation, that is, the evidence for assuming the middle Miocene age of the beds at Cabo Blanco.

W. P. Woodring[6] has determined 23 different kinds of molluscs from the collection from Cabo Blanco, sent to him for determination. Extracts from his summary are as follows.

> Collection is considered to represent a horizon equivalent to part of the Gatun formation of the Panama Canal Zone and is assigned to the middle Miocene. The Gatun fauna is a readily recognized unit in an extensive area along the west and south sides of the Caribbean Sea extending from Mexico to Venezuela. The recent *Macrocallista maculata* is the most abundant species in the collection. This species is represented by a small form in the lower Miocene of Florida and Brazil; the typical form occurs in the Gatun formation and in strata of equivalent age in Colombia and Falcón. It is improbable that the collection represents a horizon younger than middle Miocene.

Quite independently of Woodring's determination of molluscs, about a dozen different forms of foraminifera were described by G. E. Tash,[7] who comes to the conclusion that the samples from the Cabo Blanco beds are definitely Miocene and strongly suggests Miocene of the Boliver Coast (eastern shore of Maracaibo Lake).

The structural relations of the Cabo Blanco beds with the Mesozoic metamorphic rocks have been outlined by the writer and make Miocene much more probable than post-Miocene or Quaternary.

Also, the physical appearance of the Cabo Blanco beds and their apparent lithologic similarity to undoubted Miocene beds in the Paraguaná, Falcón, Rio Tuy, and Araya-Cumaná regions suggests a Miocene age.

For further reference it may be added that the question about the age of the Cabo Blanco beds has already been discussed at some length by K. Martin[8] in 1888, who assumed a Quaternary age, in contradiction to opinions expressed by A. von Humboldt,[9] G. P. Wall,[10] and H. Karsten[11] who as-

[1] Manuscript received, August 24, 1939.

[2] The Venezuelan Oil Development Company, Apartado 100.

[3] L. Kehrer, "Geology of Central Venezuela," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 5 (May, 1939), pp. 703-04.

[4] *Ibid.*, pp. 699-703.

[5] M. Kamen Kaye, "Geological Succession in Venezuela," *ibid.*, Vol. 22, No. 9 (September, 1938), pp. 1224-30.

[6] Private report to the Caribbean Petroleum Company.

[7] Private report to the Caribbean Petroleum Company.

[8] K. Martin, "Geologische Studien über Niederländisch Westindien," in *Bericht über eine Reise in Niederl. Westindien*, by E. J. Brill, pp. 227-29. Leiden (1888).

[9] A. von Humboldt, *Reise in die Aequinoctial Gegenden des neuen Continents*, Vol. 5. Stuttgart (1861).

sumed a Tertiary age. W. Sievers,[12] A. Jahn,[13] R. A. Liddle,[14] Charles Schuchert,[15] and others accepted Martin's determination in their publications.

From Martin's description (pp. 227–29), it appears that his type locality is somewhat east of Cabo Blanco in horizontal or slightly north-dipping beds near the seashore (normal depositional dip).

The type locality, however, is west of Cabo Blanco in fairly steep, south-dipping beds (structurally reversed dip).

It seems therefore that, besides the fairly steeply south-dipping Miocene Cabo Blanco beds, there exists a fossiliferous marine Quaternary terrace formation in the La Guaira-Maiquetia-Cabo Blanco-Catia de la Mar area. This shows a slight, normal, depositional north dip. This almost horizontal Quaternary formation seems to overlie transgressively the Cabo Blanco beds.

As there is no reason to doubt the determinations of Martin (resp. M. M. Schepman), it seems fairly clear that Martin's age determination refers to the younger, marine-terrace formation only and not to the Cabo Blanco beds.

Similar flat Quaternary to Recent fossiliferous, marine beds are known to the writer from the Falcón and Paraguaná coasts and other parts along the Venezuelan seashore.

Most probably Kamen Kaye has exclusively these Quaternary formations in mind when a middle Miocene age of the Cabo Blanco beds does not find favor with him.

For the sake of more completeness it may be added that the well known Punta Gavilan beds of eastern Falcón, described by Rutsch[16] and Suter,[17] represent a similar marine terrace formation, however of (Mio?-) Pliocene age.

With reference to the lower Miocene age of the Galera sandstone which is doubted by Kamen Kaye, it should be taken into full consideration that there exists still considerable difference of opinion among the paleontologists themselves about the exact boundary between Miocene and Oligocene.

Fossils considered by one paleontologist as lower Miocene might be placed by another in the upper Oligocene. This is clearly evidenced by the statements of Hoffmeister[18] and others.

[10] G. P. Wall, "On the Geology of a Part of Venezuela and Trinidad," *Quar. Jour. Geol. Soc.*, Vol. 16 (London, 1860), pp. 460–70.

[11] H. Karsten, *Géologie de l'ancienne Colombie Bolivarienne, Venezuela, Nouvelle Grenade et Ecuador*. Berlin (1886).

[12] W. Sievers, *Zweite Reise in Venezuela in den Jahren 1892–93*, pp. 155–56. Hamburg (1896).

[13] A. Jahn, *Esbozo de las formaciones geológicas de Venezuela*, pp. 89–91. Caracas (1921).

[14] R. A. Liddle, *The Geology of Venezuela and Trinidad*, pp. 351–52. Fort Worth (1928).

[15] Charles Schuchert, *Historical Geology of the Antillean-Caribbean Region*, p. 682. New York (1935).

[16] R. Rutsch, "Die Gastropoden aus dem Neogen der Punta Gavilán in Nord Venezuela," *Abh. Schweiz Pal. Ges.*, Bd. 54–55 (Basel, Switzerland).

[17] H. N. Suter, "Geologic Notes on the Punta Gavilán Formation and on the Eastern Part of Falcón," *Bol. Geol. y Mineria*, Tome 1 (Caracas, 1937), pp. 269–79. Edition in English.

[18] Wm. S. Hoffmeister, "Aspect and Zonation of the Molluscan Fauna in the La Rosa and Lagunillas Formations, Bolivar Coastal Fields, Venezuela," *Bol. Geol. y Mineria*, Tome 2 (Caracas, 1938), pp. 103–122. Edition in English.

With regard to other questions raised by Kamen Kaye, which have been discussed in other places, the reader may refer to various papers in the *Boletin de Geologia y Mineria*.[19]

[19] *Boletin de Geologia y Mineria* (Ministerio de Fomento, Caracas, Venezuela), Tome 1, Nos. 2, 3, 4 (1937), pp. 20, 59–66, 278–79; Tome 2, Nos. 2, 3, 4 (1938), pp. 82–83, 152–54. Editions in English.

THE GEOLOGIST AND THE WELL-SPACING PROBLEM[1]

WILLIAM W. PORTER II[2]
Los Angeles, California

In stressing the relationship between geology and well spacing, and the necessity of a reasonably correct geological diagnosis of the nature and extent of the reservoir to make engineering results workable in practice, Kraus has developed a subject which must be carefully considered if engineering data on the subject are to be made applicable. This is particularly important since the well-spacing problem is closely related to laws restricting drilling, and to current theories of ownership in place. From the relative rarity of geological articles on the subject it seems that Kraus is correct in believing that geologists have been rather indifferent to the problem. However, geologists' apparent lack of interest may not be due to unfamiliarity with modern production methods, but perhaps to the fact that many conclusions are less revolutionary from a scientific standpoint than they are from legal and economic standpoints. The idea of conserving gas energy to produce fluid is known to anyone who has operated a siphon bottle. Yet the promptness with which the results of some of the engineering investigations have been applied as groundwork for new legal precepts, and as bases for oil-control statutes may account for the lag in geological opinion. If so, it gives point to Kraus' contention of the necessity for correlation between engineering and geological principles in oil production. The situation is not improved by illogical or biased handling of some of the data. An example is the report by the Special Study Committee on Well Spacing presented to the Committee of the Board of Directors of the American Petroleum Institute in May, 1938. Part of the summary of this report is quoted by Kraus. Under "Engineering Principles in Production of Reservoir," paragraph 4 reads as follows.

> 4. The same or greater efficiency of recovery can be obtained by wider spacing at lower rates of flow per acre than by close spacing at excessive rates of flow per acre.

The logic is irrefutable, but what does it mean? No more than it says, of course, which is simply an involved statement of a truism. "Lower rates of flow per acre" must mean controlled or restricted flow, and presumably means in conformity with sound engineering principles, or with good production methods. "Excessive rates of flow per acre" certainly means a flow rate exceeding that dictated by sound engineering, or in other words, bad production methods. The "conclusion," then becomes a thoroughly unscientific statement, that is, the same or greater efficiency can be obtained by wider

[1] Edgar Kraus, "The Geologist and the Well-Spacing Problem," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 10 (October, 1938), pp. 1440–46. Discussion received, November 6, 1939.

[2] Consulting geologist, 244 South Grammercy Place.

spacing and good production methods than by close spacing and bad production methods.

Such sophomoric reasoning, the comparison of production results on different spacing grids under *unlike* production methods, is not uncommon in recent literature. It is mentioned here not as a quibbling criticism of phraseology, but as an objection to a practice which, if not deliberately misleading, at least adds confusion to an issue that greatly needs clarity.

In discussing the geological viewpoint, Kraus mentioned the important point of the time required for drainage under any particular spacing program, and also the relation between the rate of flow, though not necessarily the ultimate production, and the "geological limits" of the reservoir, that is, the relation of the rate of drainage under any particular spacing plan to the various structural and stratigraphic irregularities which affect the distribution and migration of the oil in the reservoir. This relationship has frequently been ignored in well-spacing recommendations. Since there are numerous spacings which will afford efficient recovery if the wells are produced under modern engineering-production methods, the spacing program selected will be related to the rate at which it is desired to drain the reservoir. If operator X has ample reserves to meet his current needs and has burdensome drilling obligations elsewhere, he will probably favor a slow extraction program in a new field. But if operator Y is not burdened with other drilling obligations and has a need for production, and if he is willing and financially able to carry on a more rapid extraction program, he will favor closer spacing. Since either program can, within reason, achieve efficiency of recovery under proper production methods, the real problem is neither engineering nor geological, but economic. It is related to the reserve, market, and cash positions of the two operators. Either program can be carried out in conformity with modern engineering methods to achieve efficient ultimate recovery of reservoir fluids; and the engineering data of neither can rightly be urged as a basis for statutes prohibiting the other.

The writer's paper[3] referred to by Kraus was unfortunately not clear in two respects. Kraus fails to find data which would preclude wider spacing in stratigraphic accumulations, and questions that examples of widely varying potentials are any conclusive measure of oil in place or reservoir conditions.

The writer made no attempt to preclude any particular spacing, but maintained, and still does, that the geological conditions mentioned, and also those mentioned by Kraus, are overwhelmingly important enough to preclude design of a spacing program by law. In the Wilmington field, Los Angeles basin, California, spacing programs continue to be modified even after more than 700 wells have been drilled. During the course of development it was found that at least five fault blocks comprise the field, and that production and spacing problems are different on the different blocks. The principal fault movement took place prior to the deposition of most of the Pliocene section; consequently, it could not be recognized "early in the life of the field." Read Winterburn, petroleum engineer for Union Pacific Railroad, the principal operator in the field, concludes[4] 3 years after discovery and when

[3] William W. Porter II, "Geological Limitations to Oil Law," *Bull Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 5 (May, 1938), pp. 565–73.

[4] Read Winterburn, "Effect of Faulting on Accumulation and Drainage of Oil and Gas in the Wilmington Field," read at the Los Angeles meeting, Petroleum Division, Amer. Inst. of Mining and Metallurgical Engineers, October, 1939.

more than 700 producing wells have been drilled, that "[fault] block III will be developed with a wider average well spacing than any of the other structural blocks . . . ." Spacing has also been modified by the faults, themselves, in order that wells will adequately drain the areas of the individual fault blocks which are separated from each other with at least enough effectiveness to allow differential pressures of 400 pounds per square inch on opposite sides of faults. These conditions do not preclude worth-while efforts to solve the well-spacing problem, but they do preclude the establishment *by law* of any design based on information available early in the life of the field.

Kraus objects that the writer's

> examples of widely varying potentials given are not at all convincing since many workers do not consider potentials a very conclusive measure of either oil in place or of reservoir conditions. In any event, even these large differences in local permeability, unless actual dry spots occur within the limits of the reservoir, have little bearing on the well-spacing problem.

The criticism is well taken because the writer neglected to include supporting data. As a matter of fact, however, widely varying potentials are a rough measure of oil in place and of reservoir behavior at Wilmington, because the high potentials are not due to differences in permeability, but to the thickness of oil sand encountered. High potentials at Wilmington are rather consistently related to local areas of greater thickness of saturated oil sand, and consequently to areas of greater ultimate production per acre and with a greater volume of oil in place per acre. Potential is also related to the amount of oil in place in buttressed sand reservoirs. In the example given, the highest location structurally had 40 feet of oil sand and a potential of less than 25 barrels per day. It rapidly became non-commercial and was abandoned. Location 660 feet east, on a different property, had 263 feet of oil sand and a potential of more than 200 barrels per day, and is still an oil well. There is obviously more oil in place under the 40 acres under which is 263 feet of oil sand than under the offset 40 acres with only 40 feet of oil sand. Lyndon L. Foley[5] recognizes the implication of such conditions in relation to well-spacing. He says:

> There are reservoirs containing small disconnected zones with relatively large accumulations of petroleum. There are fields in which the production comes from fractures; fields of erratic porosity and fields badly faulted are examples of this class. The principles applied to more uniform pools may not apply to fields of this kind, and it may be necessary to drill more closely as a sporting proposition in order to be sure that all of the rich zones are tapped.

The writer believes that these matters have an important bearing on the well-spacing problem, and that since control of well-spacing by law is currently in vogue in several states, the existence of such features and their quantitative importance makes them definite limitations to well-spacing law. *Required* wide spacing that would prevent the discovery of local areas of high productivity would grossly violate equities and would be contrary to conservation principles. Many valuable data on well-spacing have been made available recently, but the conclusions drawn therefrom lose value when, while yet immature, they cease to be suggestions and become requirements.

[5] Lyndon L. Foley, "Spacing of Oil Wells," *Trans. Amer. Inst. Min. Met. Eng., Petroleum Development and Technology, 1938*, p. 22.

REPLY[1]

EDGAR KRAUS[2]
Carlsbad, New Mexico

Mr. Porter's fair discussion of the paper, "The Geologist and the Well-Spacing Problem," emphasizes the inadvisability of establishing well-spacing patterns and programs by law. With this view, no fair-minded engineer or geologist could disagree. To avoid, however, an ultimate spacing that is entirely too close from either geologic, engineering, or economic viewpoints, it is desirable that any conservation or proration statute provide for an allocation unit large enough to avoid such excessively close spacing yet will enable an operator, if he so desires, to drill more than one well on a unit and so arrive at a well density which seems desirable on the basis of the factors mentioned in his discussion, without forcing other operators against their own desires to drill to a similar pattern.

Mr. Porter's criticism of the wording of paragraph No. 4 of an early recommendation by the Special Study Committee on Well Spacing does not recognize that this report was designed primarily to draw to the attention of operators a very practical "truism." That this was the intent is evidenced by the third from the last paragraph of the paper under discussion, but a more recent quotation by R. D. Wyckoff[3] expresses it and other equally important viewpoints so well that it is repeated *verbatim* here.

> . . . all evidence points to the conclusion that in a strictly gas-driven system the percentage of oil recovery is substantially independent of the distance from the well. While additional detailed study is required to provide further justification, we feel that, in so far as this particular phase of the problem is concerned, it may safely be dismissed as being of only secondary importance compared with other factors. In other words, to the extent that the physics of flow of mixed fluids is alone concerned, the well-spacing problem in an oil field is comparable to that in a gas field and is relegated to the economic phase. Economics alone will serve to prevent development on spacing so wide as to be absurd.
>
> I wish further to emphasize that these remarks do not mean that the spacing problem is non-existent. On the contrary, in addition to the economic phase mentioned, there are other factors. While the experimental evidence already referred to indicates that the *importance of the spacing factor alone upon recovery is relatively insignificant*, it also serves to stress the fact that if high recovery, which is the essence of the problem, is to be obtained, careful attention must be given to numerous other factors which for brevity may be referred to as "good practice" in the utilization of reservoir energy. By this is meant the proper consideration of the reservoir configuration and characteristics as a whole whereby advantage may be taken of expanding gas caps or encroaching water. This requires not only the proper location of wells with respect to the structural features of the reservoir but a proper adjustment of the rates of withdrawal from the reservoir. Since there are physical factors, including such obvious difficulties as gas or water coning, which limit the practical rate of withdrawal from individual wells, the spacing problem enters the picture. It is to these technical phases that the well-spacing problem has, in my opinion, been shifted since the more fundamental physical question seems to have dissolved.

[1] Manuscript received, November 13, 1939.

[2] Atlantic Refining Company, Box 808.

[3] Report of Special Study Committee on Well Spacing," *Proc. A.P.I. 9th Mid-Year Meeting*, Vol. 20M (IV), (1939).

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to members and associates.

PETROLEUM PRODUCTION ENGINEERING—OIL FIELD EXPLOITATION, BY LESTER C. UREN

REVIEW BY K. C. HEALD[1]
Pittsburgh, Pennsylvania

Petroleum Production Engineering—Oil Field Exploitation, by Lester C. Uren. Second Edition. McGraw-Hill Book Company (1939). 531 pp., 258 illus., list of contents, and subject index. Price, $5.00.

This companion volume to *Oil Field Development*, by the same author, which was published in 1934, deals with the recovery or extraction of oil and gas from fields and the transportation of these substances. Of necessity there is an overlap between *Oil Field Exploitation* and *Oil Field Development* and therefore they are not supplementary in the sense that each supplies information that is lacking in the other, but the overlap is by no means so serious as to create the impression that one or the other of these two books is superfluous.

The book is planned to provide the descriptive background for a university course in petroleum production methods, "and to furnish information that the student of petroleum engineering requires in gaining a proper perspective of the petroleum industry and a knowledge of its terminology, equipment, and methods." The author also hopes that it may be serviceable to any who may "seek an orderly review of the methods and equipment employed and of the physical principles controlling the recovery of petroleum from its reservoir rocks."

Presumably the students for whom the book is primarily intended have laid the foundations for their engineering work in basic courses dealing with mathematics, physics, chemistry, and English, and the purpose of the book, therefore, is primarily to familiarize the student with the processes and the equipment to which he must apply this basic training and to lay before him the physical conditions with which he must cope.

On the whole it seems to the reviewer that these objectives have been admirably achieved. The work is remarkably comprehensive and the presentation is orderly, simply worded, and easily understandable. In places the author may have gone too far in the interests of simplicity by presenting debatable conclusions as facts, but such occurrences are rare.

The book is replete with illustrations, diagrams, tables. Whether or not economy of volume by omission of part of this material would have been justified is a matter of opinion. The reviewer feels that descriptions and illustrations of equipment now in use by an industry that is experiencing a rapid change of technological procedure must be behind the times when, in the form of illustrations in a text book, they reach the student. It seems far less vital to present illustrations of many of the appliances and assemblies in current use than it is to make sure that the student grasps the purpose of the fundamental design of the equipment and understands the factors that make

[1] Gulf Oil Corporation. Manuscript received, October 28, 1939.

for strength and those that make for weakness. For such purposes a limited number of diagrammatic illustrations are far more effective than an unlimited number of photographic reproductions of equipment in use.

It probably matters little whether or not the young engineer, when he first steps on the derrick floor, knows the trade name and the name of the manufacturer of each piece of equipment. If he aspires to such knowledge he also should add to his equipment a lexicon of colloquial oil-field terms, startling in their descriptiveness. The important thing is the fundamental knowledge that will permit him to understand both what he sees and what he hears. If he can do these things he may become a real engineer, as contrasted to a graduate of an engineering school. Of course there is no objection to a student having both fundamental and detailed knowledge and presumably, when this book is used in conjunction with the lectures that form a part of a course in petroleum engineering, emphasis will be placed where it will be of greatest benefit, so this criticism is not serious.

The book is in no sense a hand book or manual of operations. From it the student or the casual reader may learn a great deal about what has to be done but little about the actual procedure involved, the manipulations, the precautions, the "tricks of the trade" in doing them. Any attempt to comprehensively furnish this information would probably more than double the size of the volume and the reviewer feels that the author was wise to include little material of this sort in preference to treating this aspect of oil exploitation inadequately. The matter is mentioned only to indicate that although the working engineer can profit greatly from the study of this volume, he should not acquire it with the thought that it will explain the details of the actual operations he must perform.

The reviewer believes this is the most adequate and serviceable book thus far published dealing with oil-field exploitation, and that it deserves a place in the library of every petroleum engineer who would be truly familiar with his field of activities.

TEXAS OIL AND GAS SINCE 1543, BY C. A. WARNER

REVIEW BY F. B. PLUMMER[1]
Austin, Texas

Texas Oil and Gas Since 1543, by C. A. Warner. 487 pp., 32 figs., 5 maps, and numerous tables. Fabrikoid binding. Gulf Publishing Company, Houston, Texas (1939). Price, $5.00.

This new publication, which meets a long-felt want for an authoritative book on the history of the development of the petroleum industry in Texas, is more than a history of the oil industry; it is, in fact, a comprehensive treatise dealing with the history, geology, structure, economics, politics, and statistics of the oil fields in Texas since the first oil was discovered, written in an interesting and almost romantic style.

The book is divided into eleven chapters. The first two deal with the general history and importance of the oil industry in Texas. The third chapter summarizes the general features of the stratigraphy and structure of the dif-

[1] University of Texas Bureau of Economic Geology. Manuscript received, November 1, 1939.

ferent oil provinces. Six chapters are devoted to a discussion of the salient facts concerning the oil resources and their development in the six principal districts of the state, namely, East Texas, Gulf Coast, North Texas, Panhandle, Southwest Texas, and West Texas. Another chapter presents a series of important, well selected, historical documents, records, and statistics that constitute an authentic sourcebook of oil history and a compendium of production tables, conveniently arranged by counties and districts. The final chapter is a bibliography of all the important publications dealing with the development of the petroleum industry in the Southwest.

The historical accounts are written interestingly and include a wealth of details, which show a large amount of painstaking research by the author, as well as many items that one does not expect to find in the usual sedate historical treatment. For example, in the account of the early development of the Sour Lake field in the Gulf Coast district the author writes that Sour Lake continued to be a resort frequented by many visitors, particularly by those afflicted with skin diseases and that many cures were credited to the well known colored man, Dr. Mud, whose "applications consisted of muds of different color and texture," and that "the results secured were often amazing." Thus along with the history of Sour Lake we are furnished details concerning the origin of mud-packs and modern cosmetic practices. Such digressions add a freshness to the author's style and interest to the book, which in no way detract from the exactness of the historical treatment.

The maps and diagrams are well chosen and supplement and explain the text. Most of the illustrations are published for the first time and reproduce features of outstanding interest, as, for example, the first rotary table introduced into Texas and the discovery well in the first Texas oil field at Oil Spring.

The large number, completeness, and careful arrangement of the statistical tables constitute a real feature of the final pages. The author has here brought together a large amount of scattered data and has carefully checked and edited them. The production data alone will be worth the price of the book to many.

SOME MEMORIES OF A PALAEONTOLOGIST, BY WILLIAM BERRYMAN SCOTT

REVIEW BY CAREY CRONEIS[1]
Chicago, Illinois

Some Memories of a Palaeontologist, by William Berryman Scott. 342 pp., portrait. Princeton University Press, Princeton, New Jersey (1939). Price, $3.00.

This is a charming and intimate autobiography by one of North America's most distinguished vertebrate paleontologists and a former president of the Geological Society of America. Beginning with the author's birth in Cincinnati in 1858, the story ranges through more than eighty years of a life which has throughout been full of color and rich with varied experiences. Professor Scott who comes from a distinguished line of forebears, including

[1] Walker Museum of Paleontology, University of Chicago. Manuscript received, November 4, 1939.

Benjamin Franklin, knew Princeton as early as the horse-and-buggy days of the sixties, experienced its college life during the seventies when tin tubs and dirt roads were the rule, and taught at the institution at a time when its Board of Trustees did not even permit President Patton to have a stenographer.

As a student at Oxford, as well as on the continent, Scott's opportunities for meeting the "personalities" of the European scientific scene were almost unparalleled, nor did he fail to make contacts in the non-scientific world. Through the pages of this book one can catch intimate glimpses of Oscar Wilde, James Bryce, Balfour, and Tyndall, the last of whom Scott thought "a remarkable snob who could talk of no one without a title." According to Scott this "eminent physicist was giving a public lecture at the Royal Institution . . . . On the other side of the table an experiment was in progress; turning to look at it the lecturer noted that it was going wrong . . . . Instead of taking the time to run around the end of the long table, he stepped back and took a flying leap over it, amid a tumult of applause from the audience. and set the experiment right. The *mise en scène* had been carefully prepared, the experiment arranged to miscarry and the leap practiced for a week beforehand." Scott also tells many a fine tale about Huxley, and throws new light on the character of President Woodrow Wilson through a series of pungent anecdotes about the man who, although always a great friend, was never idolized.

For 46 years Professor Scott taught geology and paleontology at Princeton and was a vital and colorful part of the brilliant passing parade of great and near-great which made the college the important intellectual focus it was at the turn of the century. Living in some of the most stirring of scientific days, Scott thus saw the gradual establishment of the modern school of scientific investigation, witnessed the dawn of Darwinism, saw the character of academic life change from leisurely, almost colonial, charm to the business-like brusqueness of modern graduate schools; and he began his geological exploration in the great and unknown west not long after the Civil War when such investigation was never completely devoid of guerrilla Indian warfare. Scott's researches in paleontology also formed the excuse for extended travels in Europe, South America, and South Africa, where, as usual, he contrived to meet interesting people and to run into exciting experiences. Through the entire story runs the history of Henry Fairfield Osborn, life-long friend, colleague, and collaborator. The very incident which prompted Osborn and Scott to take up paleontologic work is delightfully recounted and the old controversies between Cope and Marsh live again more vividly than before in these pages.

The book at hand is a greatly reduced version of a biography which Professor Scott wrote as a family record for his children. To the statement that "autobiography is necessarily fiction" Scott makes definite denial so far as this particular work is concerned. The story, he says, is only a sketch but an undistorted one. "I have a good memory, nothing phenomenal, but still trustworthy, and there is before me a very long series of letters written to my wife both before and after our marriage. These letters, supplemented by diaries, have enabled me to make out an unusually complete narrative—these chapters—are not fiction in any sense—I have no grievances to exploit or enemies to belabor." This is probably a fair appraisal, and all those who have

heard Professor Scott officiate as a toastmaster in his inimitable style will not be surprised that his story is sparkling and witty throughout.

The biography for the most part terminates in 1925, the 14 remaining years being covered in half as many pages. A great sorrow befell Professor Scott when in 1935 Henry Fairfield Osborn died. In their student days the German scientist Davidoff was very much amused by a phrase, "Scott ohne Osborn," which he himself coined, with facetious reference to the ubiquitous "Scott und Osborn." Since 1935, to Professor Scott's great regret, it has indeed had to be "Scott ohne Osborn."

In concluding his biography Scott appropriates the words that Darwin used near the end of his life, "I feel no remorse from having committed any great sin, but have often and often regretted that I have not done more direct good to my fellow creatures." This was a ludicrously modest statement for Darwin. It is almost equally modest for Professor Scott, whose good deeds and good works, including this book, are legion.

RECENT PUBLICATIONS

AFRICA

*"Outline of the Tectonics of the Earth, with Special Emphasis upon Africa," by Leo Picard. *Bull. Geol. Dept. Hebrew Univ.*, Vol. 2, Nos. 3–4 (Jerusalem, Palestine, July 1, 1939). 68 pp., 18 figs.

Geologie der Deutschen Kolonien in Afrika (Geology of the German Colonies in Africa), by E. Krenkel. 272 pp., 5 pls., 65 figs. Cloth. Gebrüder Borntraeger, Berlin (1939). Price, RM 24, less 25 per cent on orders outside Germany.

ARGENTINA

*"Aerial Views, Active Faults, and Earthquakes of Mendoza," by Enrique Fossa-Mancini. *Bol. Inform. Petroleras*, Vol. 16, No. 179 (Buenos Aires, July, 1939), pp. 45–78; 40 figs. In Spanish.

ASIA

"Central Himalaya: Geological Observations of the Swiss Expedition of 1936," by Arnold Heim and August Gansser. *Denkschriften der Schweizerischen Naturforschenden Gesellshaft*, Band 73, Abh. 1 (1939). 245 pp., 162 figs., 86 photos, colored map. In English. *Abstract by G. M. Kay, in *Amer. Jour. Sci.*, Vol. 237, No. 11 (New Haven, Connecticut, November, 1939), p. 844.

CALIFORNIA

"Geology and Ground-Water Hydrology of the Mokelumne Area, California," by A. M. Piper, H. S. Gale, H. E. Thomas, and T. W. Robinson. *U. S. Geol. Survey Water-Supply Paper 780* (1939). 230 pp., 22 pls., 28 figs. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $2.25.

*"Miocene Stratigraphy of the Easternmost Ventura Basin, California: a Preliminary Statement," by Richard H. Jahns. *Amer. Jour. Sci.*, Vol. 237, No. 11 (New Haven, Connecticut, November, 1939), pp. 818–25; 1 stratigraphic chart.

CHILE

*"Introduction to the Geology of Northwest Peru and Southwest Ecuador," by A. Olsson. *Annales Combus. Liquides*, Vol. 14, No. 3 (Paris, May, 1939), pp. 551–604; 3 pls. In French.

COLOMBIA

**The Petroleum Industry in Colombia*, by Felix Mendoza and Benjamin Alvarado. Brief historical account and outline of the present status of the industry; an essay on the oil geology of the country; and a résumé of petroleum legislation. Pp. 113–217; Figs. 30–57; in English. Pp. 1–112; Figs. 1–29; in Spanish. Ministerio de la Economia Nacional, Departmento de Petroleos, Bogota (April, 1939). Paper, 9×12.5 inches.

ENGLAND

*"The Upper Part of the Lower Greensand around Folkstone," by R. Casey. *Proc. Geol. Assoc.*, Vol. 50, Pt. 3 (London, September 29, 1939), pp. 362–78; 1 fig., 1 pl.

*"The History of the Lower Cretaceous Period in England," by J. F. Kirkaldy. *Ibid.*, pp. 379–417; 7 figs., 6 pls.

GENERAL

Finding and Producing Oil, prepared by the American Petroleum Institute Division of Production (50 West 50th St., New York, October, 1939). 338 pp., 157 illus., 1,671 bibliographical citations. "An attempt to overcome the lack of concentration in convenient form of much important reference information, available throughout the United States." Contains 15 sections with 76 separate articles. Price: $3.00 postpaid in the United States; $3.50 in foreign countries.

The Birth of the Oil Industry, by Paul H. Giddens. 216 pp., Macmillan Company, London. Price 14 s.

Gebirgsbildung und Vulkanismus (Mountain Building and Plutonism), by Hans Becker. 220 pp., 129 figs. 6.5×10 inches. Gebrüder Borntraeger, Berlin (1939). Price: paper, RM 16; cloth, RM 17.20; less 25 per cent on orders outside Germany.

Principles of Sedimentation, by W. H. Twenhofel. 610 pp., 44 figs. Cloth. 6×9 inches. McGraw-Hill Book Company, Inc., New York (1939). Price, $6.00.

GERMANY

**Jahrbuch der Deutschen Mineralölwirtschaft* (Yearbook of the German Oil Industry), edited by Karl-Heinrich von Thümen. 662 pp., tables, charts, illus. Contains 7 sections: (1) General; (2) Organized Structure; (3) Legal Situation; (4) Production and Consumption; (5) Science and Research; (6) Statistics; (7) Supplement. Clothbound. 6×9×2 inches. Verlag Naturkunde und Technik, Frankfurt A. M. (1939). Price, RM 9.60.

ILLINOIS

*"Illinois Geologic Trends Better Defined," by W. V. Howard. *Oil and Gas Jour.*, Vol. 38, No. 24 (Tulsa, October 26, 1939), pp. 34–35, 43–44; 3 tables, 2 maps.

*"Six Horizons Producing along Wabash Valley," by Keith A. Spitznagel and Hastings Moore. *Ibid.*, pp. 54–56, 70; 1 structure map.

*"Magnetic Gradient Maps for Illinois and Southern Michigan," by W. P. Jenny. *Oil Weekly*, Vol. 95, No. 9 (Houston, November 6, 1939), pp. 22–30; 5 figs.

IRELAND

*"Geology of South-East Ireland, together with Parts of Limerick, Clare and Galway," by Louis B. Smyth and others. *Proc. Geol. Assoc.*, Vol. 50, Pt. 3 (London, September 29, 1939), pp. 287–351; 29 figs., 1 pl.

MEXICO

*"Geological Reconnaissance in Northern Sierra Madre Occidental of Mexico," by Robert E. King. *Bull. Geol. Soc. America*, Vol. 50, No. 11 (November 1, 1939), pp. 1625–1722; 9 pls., 7 figs.

*"Paleogeographic Studies in Northeastern Sonora," by Ralph Imlay. *Ibid.*, pp. 1723–44; 4 pls., 2 figs.

*"Permian Fusulines from Sonora," by Carl O. Dunbar. *Ibid.*, pp. 1745–60; 4 pls.

MISSISSIPPI

*"Mississippi Oil Discovery Indicates Vast New Reserve," by H. D. Easton. *Oil Weekly*, Vol. 95, No. 9 (Houston, November 9, 1939), pp. 13–14; 2 figs.

MONTANA

"Fossil Plants from the Colgate Member of the Fox Hills Sandstone and Adjacent Strata," by R. W. Brown. *U. S. Geol. Survey Prof. Paper 189-I* (1939), pp. 239–75, Pls. 47–63, Fig. 30. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.15.

NEW YORK

*"Catskill Facies of New York State," by Ely Mencher. *Bull. Geol. Soc. America*, Vol. 50, No. 11 (New York, November 1, 1939), pp. 1761–94; 2 pls., 2 figs.

NORTH AMERICA

Geology of North America, edited by Robert Balk and Rudolf Ruedemann. 643 pp., 14 pls., 53 figs. In English. Gebrüder Borntraeger, Berlin (1939). Cloth. Price, RM 16.

OKLAHOMA

*"Geology and Ground Water Resources of Texas County, Oklahoma," by Stuart L. Schoff. *Oklahoma Geol. Survey Bull. 59* (Norman, Oklahoma, 1939). 248 pp., 12 tables, 5 pls., 13 figs.

"Subsurface Geology and Oil and Gas Resources of Osage County, Oklahoma, Part 2, Townships 22 and 23 North, Ranges 8 and 9 East," by C. T. Kirk, H. D. Jenkins, Otto Leatherock, W. R. Dillard, L. E. Kennedy, and N. W. Bass. *U. S. Geol. Survey Bull. 900-B* (1939), pp. 47–82, Pl. 2. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.40.

"Subsurface Geology and Oil and Gas Resources of Osage County, Oklahoma, Part 3, Townships 24 and 25 North, Ranges 8 and 9 East," by N. W.

Bass, L. E. Kennedy, J. N. Conley, and J. H. Hengst. *Ibid., Bull. 900-C* (1939), pp. 83–129, Pl. 3. Price, $0.40.

PALESTINE

*"The Geology of New Jerusalem," by Leo Picard. *Bull. Geol. Dept. Hebrew Univ.*, Vol. 2, No. 1 (Jerusalem, May, 1938). 12 pp., folded plate of 2 geologic sections.

RUSSIA

*"Geologic Structure of Wolga-Emba Oil Region and Its Economic Importance," by N. Polutoff. *Kali, verwandte Salze und Erdöl*, Vol. 33, No. 18 (Berlin, October 1, 1939), pp. 178–81 (first installment), 1 fig. Verlag: Wilhelm Knapp, Halle (Saale), Mühlweg 19. In German.

SOUTH AMERICA

Report on the Geology of the Superficial and Coastal Deposits of British Guiana, by D. R. Grantham and R. F. Noel-Paton. 122 pp., 9 maps in folder. Geol. Survey of British Guiana. The Argosy Company, Ltd., Georgetown, Demerara (1938). Price, $1.00.

UTAH

"Artesian-Water Levels and Interference between Artesian Wells in the Vicinity of Lehi, Utah," by G. H. Taylor and H. E. Thomas. *U. S. Geol. Survey Water-Supply Paper 836-C* (1939), pp. 107–57, Pls. 12–14; Figs. 4–10. Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.15.

WEST VIRGINIA

*"Petrography and Correlation of Deep-Well Sections in West Virginia and Adjacent States," by James H. C. Martens. *West Virginia Geol. Survey*, Vol. 11 (Morgantown, 1939). 255 pp., 22 pls., 8 figs. 6×9 inches. Cloth. Price, $2.04.

WYOMING

*"Geology along the Southern Margin of the Absaroka Range, Wyoming," by John David Love. *Geol. Soc. America Spec. Paper 20* (New York, September 26, 1939). 134 pp., 17 pls., 3 figs.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

* *Journal of Paleontology* (Tulsa, Okla.), Vol. 13, No. 6 (Nov., 1939).

"Fauna of the Niagaran Nodules of the Chicago Area," by David M. Grubbs

"Ostracoda from the Weches Formation at Smithville, Texas," by A. H. Sutton, and John R. Williams

"Some Middle Tertiary Smaller Foraminifera from Subsurface Beds of Jefferson County, Texas," by J. B. Garrett.

"Some Ostracoda of the Genus *Cythereis* from the Cook Mountain Eocene of Louisiana," by D. D. Gooch

"Permian Pelecypod Genus *Liebea*," by Norman D. Newell

"Some Fusulinids from the Missouri Series of Kansas," by Frank E. Merchant and Raymond P. Keroher

"Shallow Pleistocene Marine Shell Stratum in Livingstone Parish, Louisiana," by Robert C. Bridges

"Convexity of Articulate Brachiopods as an Aid in Identification," by Eula D. McEwan

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 23, NO. 12 (DECEMBER, 1939), PP. 1867-1887, 3 FIGS.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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RESEARCH NOTES

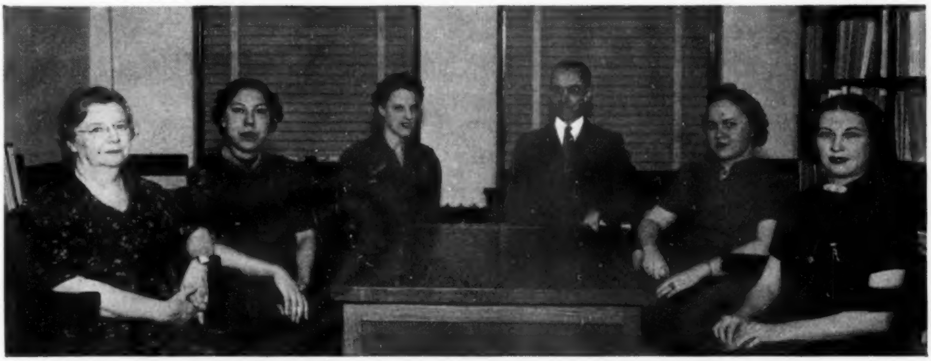
WANTED: By the research committee conference group studying the general subject of oil-field waters, the location of, and geologic data concerning, as many occurrences of oil and gas associated with fresh or low-concentration waters as possible. Will anyone, therefore, knowing of such occurrence anywhere in the world, please communicate with the undersigned, giving as much information as possible and listing references to the literature or the names of other persons who might add data on the areas described. For the purposes of this investigation, waters of concentration of total solids of less than 5,000 parts per million (5 grams per liter) are desired.

L. C. CASE
Leader, Oil-Field Waters Conference

GULF OIL CORPORATION, TULSA, OKLAHOMA
December 4, 1939

ASSOCIATION HEADQUARTERS

The national headquarters of the Association was established by the executive committee following the eleventh annual meeting in 1926. During the 9 preceding years of the Association's history, the organization's work had been carried on by the annually elected officers, and for 6 of those years the tasks of the secretary-treasurer and the editor had been performed faithfully and generously by Charles E. Decker at the University of Oklahoma and Raymond C. Moore at the University of Kansas, notwithstanding the steadily increasing demand on their limited time and energies. Headquarters office was opened, July 15, 1926, with two full-time employees, in three rooms on the top floor of the Tulsa Public Library, pending completion of the Tulsa Building to which the office was moved in November, 1927, in accordance with plans of the Tulsa Geological Society and the Tulsa Chamber of Commerce, the organizations which sponsored the establishment of headquarters in Tulsa. On May 1, 1936, the offices were moved to more suitable space at 606–610 Wright Building, the present location. In August, 1937, the secretary-treasurer's office of the Society of Economic Paleontologists and Mineralogists was established at 605 Wright Building so that now the secretarial headquarters work of both the A.A.P.G. and its Division of Paleontology and Mineralogy, the S.E.P.M., is carried on at one central location by six full-time employees.



Association Headquarters Staff, 1939

Left to right (parenthetical data show place and year in which each began work): Miss Daisy Winifred Heath (Chicago, 1922; Tulsa, 1927); Miss Gayle Robertson (Tulsa, 1930); Miss Condray Blair (Tulsa, 1938); J. P. D. Hull (Tulsa, 1926); Miss Johnnie Ruth Cassidy (S.E.P.M.; Fort Worth, 1934; Tulsa, 1937); Miss Marie Cummings (Tulsa, 1929).

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TWENTY-FIFTH ANNUAL MEETING, CHICAGO
APRIL 10–12, 1940

The twenty-fifth annual meeting of the Association will be held in Chicago at the invitation of the Illinois Geological Society whose officers are the following.

President, Verner Jones, Magnolia Petroleum Co., Mattoon
Vice-pres., M. W. Fuller, Carter Oil Co., Mattoon
Secy.-treas., E. W. Ellsworth, W. C. McBride, Inc., Centralia

The convention committee is being completed. The following committeemen have been named.

General chairman, Verner Jones, Magnolia Petroleum Co., Mattoon
Technical program, A. H. Bell, Illinois Geological Survey, Urbana
Arrangements, J. V. Howell, consulting, Mt. Vernon
Trips, M. M. Leighton, Illinois Geological Survey, Urbana
Finance, E. W. Ellsworth, W. C. McBride, Inc., Centralia

Grand Stair Hall, Stevens Hotel, Chicago, where twenty-fifth annual meeting of the Association will be held, April 10–12, 1940. Entrance to Grand Ball Room (second floor), where technical sessions will be held. Antique Lounge, at left, for exhibits. Writing Room, at right, for registration.

SOUTH TEXAS SECTION, ELEVENTH ANNUAL MEETING OCTOBER 20–22, 1939. ABSTRACTS

JOSEPH M. DAWSON
Corpus Christi, Texas

Approximately 125 geologists composed the field party of the pre-convention trip of the South Texas Geological Society from Laredo to Brownsville, October 20, and 75 were on the post-convention trip east and north of Brownsville, October 22. The technical program was presented in the Ballroom of the El Jardin Hotel at Brownsville, October 21.

Officers of the South Texas Section are: president, Willis Storm; vice-president, Dale L. Benson; secretary-treasurer, Robert N. Kolm. Chairmen of the convention committees were: field trips, W. Armstrong Price, and vice-chairman, J. M. Patterson; entertainment, Leavitt Corning, Jr., and Dunbar A. Fisher; technical program, Joseph M. Dawson, and L. W. Storm, vice-chairman; hotel, Charles Daubert and Harvey Whitaker.

The technical program follows.

1. HENRY A. LEY, president A.A.P.G., vice-president, Southern Cross Oil Company, San Antonio: Mutual Responsibilities.

2. ED. W. OWEN, secretary-treasurer, A.A.P.G., geologist, L. H. Wentz Oil Division, San Antonio: Association Affairs.

3. JOSEPH M. PATTERSON, geologist, The Texas Company, San Antonio: Surface Stratigraphy of the Eocene between Laredo and Rio Grande City, Starr, Zapata, and Webb Counties, Texas (abstract).

A cross section of the stratigraphic succession on the American side of the Rio Grande conforms to Kane and Gierhart's[1] formational divisions which were established for the most part from Trowbridge's original work. The Cook Mountain has been subdivided into three members. The subsurface top of Cook Mountain (uppermost occurrence of *Ceratobulimina eximia*) is about 500 feet below the top of the Cook Mountain as mapped at the surface.

Cycles of deposition in the Yegua and Fayette are found to be very similar. The Mier and Alamo sandstones of the Yegua and the Salineno, Roma, and Sanchez sandstones of the Fayette have a marine facies where they cross the Rio Grande into Starr and Zapata counties. Northward these marine sandstones wedge out and the shale members between become increasingly non-marine. It is suggested that each sandstone wedge and its associated shales represent a cycle of transgression and regression of the sea.

4. LEROY FISH, geologist, The Texas Company, San Antonio: Distribution and Subdivision of the Frio, Catahoula, and Oakville Formations, Starr County, Texas (abstract).

The purpose of this discussion is to carry the section from the top of the Jackson (where Patterson's paper stopped) through the Frio, Catahoula, and Oakville formations; to make a subdivision of the Catahoula; and to point out the occurrence of the Oakville formation in this area. The distribution of the formations is shown on the aerial map.

For convenience of mapping, an oyster bed at or near the top of the Jackson (Fayette) is accepted as the base of the Frio. There are 550–600 feet of

[1] W. G. Kane and G. B. Gierhart, "Areal Geology of Eocene in Northeastern Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 9 (September, 1935), pp. 1357–88.

red and green clays with thinly bedded sands, assigned to the Frio formation. Two prominent sandstone beds occur in the upper 200 feet of the formation.

The Catahoula is subdivided into three members: Fant, 75 feet; Soledad, 200 feet, and La Chusa, 1,000 feet thick (Thomas L. Bailey, *Univ. Texas Bull. 2645*).

Approximately 200 feet of pinkish chocolate-colored clays with globules of soft limestone overlies the La Chusa tuffs. These clays are distinctly different from Catahoula deposits, and are referred to the Oakville formation, due to their lithologic character and position in section.

The Catahoula and Oakville are overlapped by Lissie or post-Pleistocene conglomerate throughout north and northeastern Starr County.

5. Lee C. Smith, geologist, Sun Oil Company, Dallas: Oil and Gas Fields of the Rio Grande Valley.

6. Eugene L. Earl, geologist, Fohs Oil Company, Houston, and F. W. Mueller, geologist, Skelly Oil Company: The Sam Fordyce Field, Hidalgo and Starr Counties (abstract).

The Sam Fordyce oil and gas field is located in southwest Hidalgo and southeast Starr counties, Texas.

Magnetometer work in 1929 first indicated structure in the area; however, the first well drilled on the anomaly in 1932 was completed as a dry hole.

The discovery well of the field, which was drilled in September, 1923, by the King-Woods Oil Company, was completed in a sand in the basal Frio formation of middle Oligocene age. Subsequent development has proved the accumulation of oil and gas in other sands of the same formation.

The reservoir is a faulted anticline whose majoı axis trends northwest and southeast along the regional strike. Closure against a major fault on the updip side of the structure accounts for the oil and gas accumulation. The fault has a maximum throw of 880 feet on top of the Sam Fordyce sand, and this sand has 260 feet of producing closure.

Geologically the Sam Fordyce structure is an outstanding example of differential sedimentation during the time of fault movement. A gradual downwarping movement northeast into the Rio Grande embayment caused the thicker sediments which are found on the downthrown side of the major fault.

The productive area of the field embraces 2,000 acres, 900 acres of which are within the oil zone of the Sam Fordyce sand zone. There are 260 acres of oil production in the Wheeler sand zone, and 215 acres in the Barlow.

7. L. B. Herring, consulting geologist, Corpus Christi: Economics and Evaluation of the Oil and Gas Fields of South Texas.

8. Harold M. Smith, chemist, United States Bureau of Mines, Bartlesville, Oklahoma: Commercial Production of Synthetic Products from Natural Gas.

Presentation of 9 charts showing composition of natural gas and the products obtainable from natural gas production.

9. Eugene McDermott, president, Geophysical Service Incorporated, Dallas: Soil Surveys (abstract).

Attention was called to the important rôle that visual oil and gas seeps and mineralization phenomena have played in the location of oil and gas fields throughout the world. A. Beeby Thompson was quoted in part from his

paper entitled "The Economic Value of Surface Petroleum Manifestations," which appeared in the *Proceedings* of the World Petroleum Congress in 1933, as follows.

> An attempt is made in this short paper to show that surface indications of oil are a natural and essential phenomenon connected with oilfields rather than an unusual circumstance, and further that failure to discern such manifestations is either damaging to prospects or a reflection upon our present-day knowledge of detecting signs of the past escape of hydrocarbons.
>
> With the exception of some of the oilfields of the Eastern Mid-continental and Rocky Mountain States of U.S.A., practically all the great oilfields of the world were marked by oil and gas issues near the crests of anticlines or the apices of domes.

George Sawtelle, in a paper entitled "Salt-Dome Statistics" in the A.A.P.G. *Bulletin* of 1936, pointed out that of the 141 salt domes discovered in the Gulf Coast prior to 1936, 75 owed their discovery, in part at least, to the presence of oil or gas seeps or mineralization phenomena. This is a surprisingly large percentage in view of the crude methods of detecting such evidences. Only large gas seeps generally occurring under water could be detected and mineralization measurements depended on the chance location of water wells.

The soil survey method is merely an extension of these older methods in that it makes possible the quantitative measurement of invisible seeps and mineralization phenomena. Furthermore, such measurements may be made at predetermined locations.

Data showing soil surveys in South Texas, West Texas, New Mexico, and Oklahoma were shown. Some interesting theoretical deductions arrived at from the data of soil analysis were dwelt on briefly.

10. W. ARMSTRONG PRICE, consulting geologist, Corpus Christi: Physiographic Mapping of Quaternary Formations in Rio Grande Delta (abstract).

There has been an increasing use of geomorphologic ("physiographic") criteria in the mapping of the Quaternary formations of the northwestern coastal plain of the Gulf of Mexico. Begun by Deussen, the employment of these criteria has been increased and improved by Barton, Doering, Fisk, Howe, R. J. Russell, and the writer. Meanwhile the method has been employed along the North Atlantic coast by Cooke, MacClintock, and others. The last few years has seen a rapid advance in the method through recent studies of deltas using precise topographic data, available for the first time, and by extensive use of soil groupings in the tracing of formation outcrops. Lithologic criteria now fall in second place.

The Rio Grande delta is relatively small and contour maps with one-foot contours and modern soil maps are now available for a strip 30 miles wide across the Texas side of the delta along the Rio Grande. No other Gulf Coast delta is now so thoroughly known. Correlations have been carried from the Rio Grande to the Mississippi delta and to the terraces of the Red and Mississippi. Formations recognized are: Recent, Lake Charles (not present on Rio Grande), Ingleside (two latter replace Beaumont), Lissie, Willis, and the Pliocene Goliad. The Willis is the probable equivalent of the Uvalde and the Reynosa term was brought into use because of calcareous soil-hard-pan deposits (caliche) in the older formations, erroneously grouped into a single formation containing "limestones." The Trowbridge and present U.S.G.S. mappings are entirely replaced.

The coastal plain delta is analyzed and its component parts described.

Downwarping of the thicker coastal areas is balanced by upwarp of the interior parts of the delta plains. Oscillations of sea-level by glacial control caused entrenchment of streams between periods of high sea-level deposition. Continued warping on axes parallel with the Gulf shore lines caused each older plain to slope more steeply gulfward than the next younger one. In the younger plains, slope criteria are secondary to continuity of plains and similar relationship to shore lines traced by continuity.

Shore lines of the Cooke Atlantic coast series are recognizable at 12, 25, 45, and 75 feet above sea in spite of Gulf Coast warping, probably because the warp axes are parallel with the coast line. Higher shore lines may be present. Entrenchment is known to have followed the abandonment of the 12- and 75-foot shorelines. The formations are continued up the Rio Grande valley as terraces. Stream terraces continuous with the intermediate shore lines have not been found.

The subject is presented in outline. Detailed presentation is reserved for publication by the Geological Society of America under a grant from which a part of the work has been done.

PACIFIC SECTION, SIXTEENTH ANNUAL MEETING NOVEMBER 9–10, 1939. ABSTRACTS

R. M. BARNES
Los Angeles, California

The sixteenth annual meeting of the Pacific Section of the Association was attended by 405 registered members and guests At the luncheon in the Cocoanut Grove of the Ambassador Hotel on Thursday, November 9, president Ley gave a comprehensive talk on Association affairs and plans before 155 members. The technical sessions on the 9th were attended by nearly 400 persons and on the 10th, approximately 500 attended. High points of the technical program were the talks by Henry A. Ley, A. I. Levorsen, and E. E. Rosaire. An amended constitution was adopted at the business meeting in the afternoon of the 9th. The dinner dance in the Fiesta Room of the Ambassador Hotel in the evening of the 10th was well attended and enjoyable.

New officers of the Section are Albert Gregersen of The Texas Company, succeeding R. M. Barnes as president, and E. J. Bartosh of the Bankline Oil Company, succeeding H. D. Hobson as secretary-treasurer. The Pacific Section of the Society of Economic Paleontologists and Mineralogists elected James M. Hamill, of The Texas Company, president, succeeding W. D. Rankin, and Edward B. Fritz, of the Union Oil Company, was reëlected secretary treasurer.

The technical program follows.

1. Henry A. Ley, president, A.A.P.G., vice-president, Southern Cross Oil Company, San Antonio, Texas: Prospecting in the National Economy (abstract).

In spite of currently large petroleum reserves we should not accept a spirit of smug complacency which would relegate the need of continuing exploration to some future time. Our national economy calls for continuous and widely supported exploration—certainly the maintenance of adequate geological and geophysical arms of the industry.

2. A. I. LEVORSEN, past-president, A.A.P.G., chairman A.A.P.G. research committee, Tulsa, Oklahoma: Research Program of The American Association of Petroleum Geologists.

3. E. E. ROSAIRE, Subterrex, Houston, Texas: Geochemical Prospecting (abstract).

Geochemical prospecting can be divided into surface and subsurface geochemical prospecting.

The former relies upon the analyses of soil samples collected along the surface of the earth at shallow depths, and yields two-dimensional information and maps. Surface geochemical anomalies are associated with the presence and areal extent, but not the depth nor the relief, or favorable structure. Surface geochemical prospecting is further divided into topsoil and subsoil geochemical prospecting.

Subsurface geochemical prospecting relies upon the analyses of well cuttings and cores. It yields information in one dimension, along the vertical, and is commonly referred to as geochemical well logging.

These various forms of geochemical prospecting are discussed, and their salient features described. The geochemical data permit the correlation of various geological and geophysical phenomena which previously appeared unrelated, and, in addition, have brought to light, for the first time, other phenomena of economic as well as theoretical interest.

4. PAUL P. GOUDKOFF, consultant, Los Angeles: Facies Changes in the Upper Miocene of San Joaquin Valley (abstract).

The paper deals with the Delmontian and upper Mohnian strata of the San Joaquin Valley, which are well known for their extreme lithological variations.

On the basis of lithological and paleontological studies of material obtained from 150 wells and several surface sections the whole column has been divided into a number of units representing definite time divisions. An attempt has been made to define the principal types of micro-faunal assemblages found in different parts of each unit, to appraise the ecological significance of these types and to survey their distribution in relation to lithological variations of the sediments of each unit.

The results of the study are illustrated by lantern slides showing: (1) lithological features and organic content of the recognized facies; (2) areal distribution of the facies; and (3) isopachous maps of the Delmontian and upper Mohnian beds.

(Presented with permission of the Geological Society of America.)

5. W. F. BARBAT, Standard Oil Company of California, Los Angeles: Pliocene of the San Joaquin Valley, California (abstract).

The Pliocene of the San Joaquin Valley is defined and a description given of the sediments and the invertebrate fauna. Attention is called to the diastrophic history, the geologic occurrence of land vertebrates, and to the physical conditions under which the sediments were deposited.

To facilitate the presentation of the subject several new names for stratigraphic units, faunal zones and diastrophic disturbances must, unfortunately, be used. To chronologize the Pliocene it will be necessary to refer to some heretofore unused time names. All new names, however, are used informally.

6. MAX STEINEKE, Standard Oil Company of California, Los Angeles: Arabian Geology and Topography (abstract).

General map of Arabia shown as well as moving pictures of typical desert scenes.

7. Frank Hornkol, consultant, Los Angeles: Interpretations of Core Analyses (abstract).

Permeability is a measure of the fluid passing ability of a porous material. Porosity is a measure of the void space in the sand that can be occupied by a fluid. Water saturation of a sand is the total amount of water in per cent present in the void space in the porous material. This includes the connate water, drilling fluid, and actual water present. The larger the diameter of the core sample, the more accurate the determination. Oil saturation is only of comparative value, because in deep samples of light gravity oils, only the residual oil is present, the other lost because of temperature and pressure conditions present. Permeability and porosity determinations for the entire oil sand area plus bottom-hole pressure from which a specific productivity index can be determined make it possible to predict fairly accurately the gross barrels per day per foot of sand.

8. J. Q. Anderson, Union Oil Company of California, Los Angeles: Comparative Columnar Sections of the Domengine-Arroyo Hondo Sandstone Intervals between Cantua Creek and Waltham Canyon, Coalinga District, California (abstract).

Presentation of a series of slides showing 13 hand-leveled surface columnar sections of the Domengine-Arroyo Hondo sandstone intervals measured at varying distances between Cantua Creek and Waltham Canyon. Correlation of all sections is based on the "black pebble bed" or Domengine Reef. Discussion involves demonstration of lateral variation and facies changes in lithology of both intervals. Deals briefly with Domengine-Kreyenhagen contact, fossil occurrences, and contact relations of the Arroyo Hondo sand with Arroyo Hondo shale and the Moreno shale.

9. Harry B. Allen, student, University of California at Los Angeles: An Eocene Section at Point of Rocks, Kern County, California (abstract).

The sedimentary sequence and formational age of the Eocene rocks in northwestern Kern County have been the subjects of controversy. The results of recent field and paleontological work, conducted in an attempt to clarify this problem, are presented in this paper.

10. Roger Revelle, Scripps Institution of Oceanography: Problems of Sediment Transportation off the Coast of California (abstract).

Several kinds of evidence obtained in recent investigations suggest that water movements of sufficient strength to move sand grains over the bottom may exist at least occasionally at all depths in the open sea. Sediments are absent from topographic highs rising one or two hundred fathoms above the general level of the sea floor even at depths of two miles or more. Thin layers of well sorted fine sand intercalated with thicker layers of clayey muds are characteristic of inshore basins off Southern California at depths of over half a mile and at distance of thirty or more miles from land. Current velocities of nearly one-half knot were measured within two feet of the bottom at 1,100 fathoms in the Santa Cruz Basin south of Santa Cruz Island, 500 fathoms below the sill or threshold of the basin. Other similar measurements show that the strongest bottom currents shift irregularly in both speed and direction. They may be regarded as representing lateral turbulence or eddy motion in which eddies have vertical axes and are perhaps a few miles in

diameter. The presence of silts and muds on the bottom in certain areas of highest observed velocities indicates that these eddy currents are not competent to prevent all deposition. Since evenly distributed eddies cannot alone produce any net transport, other factors such as the gravitational component down slope and steady weak currents must coöperate in preventing deposition on certain areas of rocky bottom and in transporting débris to the regions of accumulation.

11. Francis D. Bode, California Institute of Technology: Geological Observations in Italian East Africa (abstract).

Topographically and geologically, Italian East Africa can be divided into three principal areas: (1) the "Ethiopian Plateau" which occupies the northwestern third of the country; (2) the "Rift Valley depression" which divides the entire country in two; and (3) the "Somaliland Plateau," the country south and east of the Rift Valley.

The Ethiopian Plateau consists of a series of tablelands, in many places of great elevation, with ranges of high and rugged mountains dispersed across its surface in rugged confusion. This high land area is composed of a thick series of lava flows which rest either on old plutonic rocks or upon a thin section of Mesozoic sediments.

The Rift Valley depression is a long, and generally narrow, trough which trends in a northeasterly direction across the country from the southwest corner of Abyssinia to near the junction of the Red Sea and the Gulf of Aden. Toward the northeast, the trough widens and the scarps which form its sides become continuous with those on the eastern side of the Red Sea and the south side of the Gulf of Aden. For the most part, the floor of the depression is covered by lava flows of Tertiary age.

The Somaliland Plateau is a great area of monotonous relief which slopes very gradually, from elevations near 5,000 feet along the Rift Valley and the Gulf of Aden, southeastward to the Indian Ocean. Most of this plateau is covered by sediments of Mesozoic and early Tertiary age.

12. Informal Symposium on Recent Petroleum Discoveries in California.

These are extemporaneous papers on areas of current interest and they are not intended for final publication at this time. Discussion is invited but deference should be given to the fact that insufficient information is available on many of these for final conclusions to be reached.

A.—L. S. Chambers, Seaboard Oil Company: East Coalinga and Amerada Area.

B.—R. Eckis, Richfield Oil Company, and G. Gariepy, Ohio Oil Company: Coles Levee Oil Field.

C.—R. W. Clark, Western Gulf Oil Company: Paloma Field.

D.—F. A. Menken, Tide Water Associated Oil Company: Strand Oil Field.

E.—J. R. Dorrance, The Texas Company: South Mountain view Field.

F.—C. E. Leach, Tide Water Associated Oil Company: Aliso Canyon Field.

G.—Vernon L. King and H. M. Preston, consultants: West Montebello Field.

H.—J. R. Dorrance, The Texas Company: Summary of Development Northern California Gas Fields.

At the annual meeting of the Pacific Section of the Society of Economic

Paleontologists and Mineralogists on November 9, the following paper was presented.

BORIS LAIMING, The Texas Company, Los Angeles: Some Foraminiferal Correlations in the Eocene of San Joaquin Valley, California (abstract).

In this paper the author presents evidence to prove the value of the smaller foraminifera as a basis for correlating Eocene strata in California.

A study of foraminiferal sequences in a number of sections taken from widely separated areas shows that the general order of superposition of microfaunal assemblages remains constant, even in the presence of variable lithologic conditions.

Charts are presented indicating the position and correlation of foraminiferal zones and formations in various surface and subsurface sections of the Eocene in San Joaquin Valley. Comparison is also made with Eocene formations in other localities.

The vertical ranges of the faunal assemblages and of some characteristic species are shown in a graphic chart.

NATIONAL RESEARCH FELLOWSHIPS

W. A. VER WIEBE
Wichita, Kansas

According to an announcement dated October 16, 1939, the National Research Council has appointed 24 Research Fellows for the ensuing year. Four of these are in the division of Geology and Geography. As usual the individuals selected all have a Ph.D. degree and are under 35 years of age. The period of appointment is for one year only and reappointments are made only in very exceptional cases. The stipend is $2,000 per annum, payable monthly in advance.

These fellowships are awarded to persons who have demonstrated a high order of ability in research, and are intended to permit the individuals to continue work along some special problem. The Rockefeller Foundation has furnished the National Research Council with an appropriation which provides for a limited number of fellowships each year.

The persons selected for the coming year are John N. Adkins who secured his Ph.D. in seismology at the University of California; Daniel Axelrod, who has a degree from the same university in the field of paleobotany; John B. Peterson, who received a Ph.D. degree in the field of soil fertility from Iowa State College; and George P. Woollard, who majored in structural geology at Princeton University and was awarded a Ph.D. degree in 1937. Dr. Woollard will continue his investigations on the geologic structure of the Atlantic Coastal Plain by means of seismic and gravity profiles.

PROSPECTING IN THE NATIONAL ECONOMY[1]

HENRY A. LEY
San Antonio, Texas

What is petroleum prospecting and what has it to do with the petroleum industry and our national economy? Is it an appendage to the oil industry

[1] Presidential talk before the Pacific Section of the Association at its annual meeting, November 9, at the Ambassador Hotel, Los Angeles, California.

or is it the keystone, holding the entire industry together—the heart and core? Is it synonymous with production?

Petroleum prospecting is a branch of the oil industry engaged in the discovery of new oil fields. Its operations are widespread from Canada into the Gulf of Mexico, and from the Atlantic into the Pacific Ocean, wherever there are rocks which may contain commercial deposits of oil. Prospecting, a more or less continuous and necessary function of petroleum capital, is solely responsible for the discovery of new petroleum reserves. Its supporting motives range from hopes of quick and spectacular profits (pure speculation) to the business of maintaining adequate supplies and adding to reserves. It employs many techniques. Its end-objective is discovery. It is not concerned with development and production. The rate at which prospecting discovers new oil fields each year, and the magnitude of its annual reserve increments, are largely, but not properly, responsible for those fear complexes which constantly plague the oil industry. Prospecting in no manner whatsoever is responsible for price and production chaos. These arise out of development after discovery and production policies.

To-day our national economy consists of many highly interdependent industries, no one of which can suffer serious dislocations without affecting all the others. Until another and better source of power and heat is found, the challenge is continuing petroleum prospecting, sufficient to ensure continuous current and adequate future supplies of petroleum. Not all producers of petroleum engage in prospecting, neither do all branches of the industry. Much prospecting capital originates outside the industry itself. One can point the case, based on greatly increased costs of prospecting and the diminishing rate of capital return, wherein the annual rate at which petroleum reserves are discovered may shockingly decline unless all branches of the oil industry share the burden of prospecting either directly or indirectly. Long-range confidence that non-oil capital will continue to shoulder much of the future burden and costs of prospecting may not be justified. There is a growing understanding of the nature and magnitude of the risks, and of a trend toward diminishing capital return.

Petroleum prospecting requires the stuff of which empire-builders are made. It is not mining, it is not manufacturing, production, or merchandising. No other major industries of this country, excepting those concerned with non-replaceable raw supplies, are faced with constant prospecting and discovery. Theirs are problems of the bookkeeper, the shopkeeper, and competition. Rarely, if ever, are they faced with complete extinction of speculative or investment capital.

Prospecting is not, and never has been, an appendage of the oil industry. Neither is it production. True, there are individual operators and even companies who by their actions and conduct of business, regard prospecting as an unessential appendage. Some act like shopkeepers and grocery men, confident that they can always fill their shelves with crude oil discovered and/or produced by the other fellow. Empire-builders, however, not only recognize prospecting as the key factor in those industries which depend on discovery, but carefully husband this tool when it is basically essential to the maintenance of that industry. Such empire-builders may be individuals, corporations, or the State.

The history of petroleum in America begins with a medicine vendor ad-

vertising the medicinal properties of petroleum. By chance or experiment he found that the medicine was also useful as a luminant and lubricant.

G. H. Bissell, a wandering teacher and journalist, attracted by Kier's medicinal advertisements, had the luminant and lubricant properties of petroleum confirmed by Professor Silliman of Yale University. Thereupon, Bissell, in 1854, set out to organize a petroleum-prospecting company. Five years later, in August, 1859, Edwin Drake, supervising representative of the Bissell Company, struck oil—a historic monument to the art of promoting capital to undertake petroleum prospecting, and the willful sinking of wells to secure supplies of petroleum.

To the medicine bottle of an apothecary, the retort of a chemist, and the art of a promoter, the petroleum industry owes each later phase of its life. As long as petroleum is a convenient and the most inexpensive source of hydrocarbons, the petroleum industry will owe its future life to the prospector and to speculative capital.

There have been few attempts to analyze the rôle of prospecting in the petroleum industry and its vital importance in our national economy. That this is true may be laid to an almost spectacular growth of consumption, relative freedom from surpluses, and to the ease with which capital necessary for prospecting could be acquired from many sources. Notions of quick and spectacular profits have brought forth many sources of capital. In later years, fevers equal to those of the frenzied gold-rush days were readily transmitted to gullible capital by incompetent men self-seduced by "closed-structure contours," the significance of which they had, and have, little or no knowledge. Nor are the cases rare where camp-followers attempt prospect promotion using geological and geophysical maps long discredited.

Five basic branches comprise the petroleum industry—prospecting, production, transportation, refining, and utilization. Through almost three generations of man, by various means of business enterprise, these five basic branches have been brought to full bloom. That bloom may prematurely wilt not because of economic, political, or social philosophies, but because the rôle and scope of each branch are not fully appraised and evaluated by the industry itself, and by each of its branches.

Market experts recognize three stages in the development and consumption of natural resources: the period of early development of the resource, the period of rapid growth of production and consumption of the resource, and the period of relatively stable consumption. No serious economic or social difficulties arise during the first two stages in the development of an industry, but with the approach of the period of relative stability irrepressible conflicts arise primarily out of unabsorbable surpluses of the resource, failure to realize quick and spectacular profits, and diminishing capital returns. As long as markets are not static, but are dynamic, each branch in an industry plays freely without informing itself fully concerning the rôle and scope of other branches in that particular industry. None has yet encompassed its field, and none is yet tramping on the other's toes.

Unprepared when a period of relative stability approaches, dissension and conflicts arise between branches. Precipitated out of dynamic constructive periods into static situations, fear complexes motivate activity. Not infrequently one branch attempts to secure profit advantages at the expense of any one or of all the other allied branches. There are innumerable Don Quixotes

about, tilting at the windmills of confusion and selfish desires. Rampant prostitution of logic and of soundly established scientific principles prevails. The entry of Government agencies, seeking by sound and/or unsound compensatory tractics, to harmonize inherent antagonisms or unsound business policies, serves only to increase the din, uproar, and confusion. There can be unpleasant aftermaths to long-continued disintegrating policies.

We are yet but a young people and a young nation which, by historic precedence, have a destiny. It seems improbable that we have fully utilized, let alone exhausted, our heritages. Shall that heritage be discarded by insidious mental prostitution? Shall a major industry of basic importance to our national economy be permitted to founder by inaction and from many false or unsound policies and concepts, which, unlike the dynamic constructive policies of empire-builders, devastate by smug complacency, luxurious optimism, and/or self-aggrandizement?

We of this Association are engaged primarily in the art of scientific prospecting, employing many techniques. We are highly skilled artisans or craftsmen rather than a profession. You may disagree with me in this definition of our status. However, you must agree with me that, unlike the learned professions of law, medicine, and theology, we do not control the use, the application, or the interpretation of our work. How many of the untrained public-at-large would hazard an attempt to practice and diagnose in the fields of law, medicine, and theology? Yet we are faced with thousands of self-made analysts and diagnosticians, all of whom regard themselves fully qualified to use our works.

Broadly and properly speaking, techniques in the art of prospecting consist not only of the scientific arms now in use or to be conceived, developed, and used hereafter, but also that important arm of casual and random prospecting which was the first arm in prospecting. Much of the backlog of our current oil reserves, and even certain of our largest individual oil fields, were discovered solely by casual and random prospecting.

One arm in exploration has been drastically curtailed, in my opinion, to the detriment of our national economy. That arm is casual and random prospecting. We are in part responsible. There is as yet no prospecting method or device which can guarantee prolific oil deposits beneath a tract of land. That none has yet been found is attested by the avidity with which management grasps at the new.

We have a large reserve of petroleum, all the result of prospecting by many methods and devices, and of many types of supporting capital funds. That these reserves are sufficient for to-day, inadequate, or a Frankenstein surplus, is a matter of viewpoint, and end-objectives. Less than 20 years ago fear was abroad in this land that our then developed petroleum reserves would shortly be exhausted, and that adequate new supplies could not and would not be discovered. Failure to think, and failure to comprehend the nature of sciences used in prospecting, the probability of new fields in each, and many new techniques in each field, were basically responsible for those dire forecasts. To-day our reserves are larger than ever, possibly adequate for the immediate future. But they have inspired a plague of fear-spawned ideas of a super-abundance. Another 20 years may see a return to the illogical fear complex of a shortage.

A stock of petroleum, which at maximum unrestricted withdrawals, prob-

ably could not provide daily market requirements for more than 6 years, without the addition of new reserves still to be discovered, should not spawn ideas of smug complacency in some and fears of super-abundance in others. In any normal economy, free from pernicious fears, current reserves would be regarded as substantial sinking funds guaranteeing not only long and continuous operations of the industry, but also security of capital invested.

Let no one think, in this transitory period of super-abundance, that any arm of prospecting can be set aside, even temporarily, without telling effects on the long-term security of a major industry on which in turn rests the prosperity of many other industries. Neither is the American public apt long to shoulder the hazards and costs of prospecting by providing much if not the major portion of prospecting funds. Prospecting is a craft, highly individualistic, requiring art and skill in planning and execution. Let me repeat again, it is made from the stuff of aggressive empire-builders. It does not flourish in a neurotic or despondent atmosphere of fears. However dormant it may be, it is capable of reasserting its vitality as has been shown repeatedly here in California and by the current, spectacular revival in Illinois and Indiana.

If it be true that this nation is but coming of age, that it is not in mid-passage from maturity to senility, petroleum prospecting has an important rôle in our national economy. Research in the sciences and fields of prospecting should be lavishly supported. The industry itself should become more conscious of the rôle and importance of prospecting and freer of manufacturing and trading concepts. It should recognize the wide gulf separating prospecting from production, and cease confusing the economic rôle and consequences of their respective functions and acts. Prospecting is discovery; production is mining.

RALPH DANIEL REED, HONORARY MEMBER

Ralph Daniel Reed, chief geologist of The Texas Company (California) and a past-president of the American Association of Petroleum Geologists, was elected to honorary membership in the Association in September, 1939. He has been a member of the Association since 1920. His inquiring and analytical nature led him to make his first contribution to geological literature in 1922 and to follow it in succeeding years with 24 major geological papers, 2 outstanding books on the geology of California, 53 reviews chiefly of foreign publications, and numerous minor articles, discussions, and notes.

His election as president of the Pacific Section, vice-president, editor, and president of the Association, and president of the Cordilleran Section of the Geological Society of America, and now his elevation to honorary membership, properly trace the recognition of his growth and distinction in the profession and this Association. He is the second past-president to have been elected to honorary membership but the youngest to have been so distinguished. His monumental written contributions to our science are overshadowed, however, by the greater work he is doing in giving his time and scholarly counsel with unfailing generosity to students and contemporaries alike.

Ralph Reed was born, April 21, 1889, in Democracy, Knox County, Ohio. While still in grade school he became interested and, without instruction,

readily became proficient in reading and writing German. This early and unusual self-tutelage qualified him later to accept the responsibility of teaching

Curtis Biltmore Studios

RALPH DANIEL REED

German during his attendance at Hiram College, Ohio, and thus to defray expenses and obtain college credits in the language. The general course at Hiram College, which included two elementary courses in geology, was com-

pleted in 3 years with the receipt, in 1913, of a Bachelor of Science degree. Ralph Reed then taught physics, chemistry, and physical geography from 1913 to 1916 in the high school at Mattoon, Illinois, and at the same time coached their football team. A somewhat passive interest in geology was enlivened by his teaching experiences which had given him the opportunity to become better acquainted with the literature dealing with physical geography and geology. The inclination of this young man toward science, his interest in problems of nature, and his desire and latent ability for research were not to be denied. In 1915 he married Mary Evangeline DeBolt who encouraged him in his desire to abandon an earlier preference for journalism in the newspaper field in favor of a professional career in geology. He enrolled for more geological courses at Ohio State University during the summer of 1916 but circumstances required him to return to teaching, this time in the high school at Orrville, Ohio, where he served as principal and again taught physics and chemistry.

The fall of 1917 saw Reed, 4 years after graduation from college, enlist as a serious student of geology under Professor Eliot Blackwelder at the University of Illinois. Two years of study, with half-time as an assistant in the department, were devoted principally to physiography, stratigraphy, paleontology, structure, and sedimentation. An intervening summer found him employed in geologic mapping in Butler and Cowley counties, Kansas, for the Gypsy Oil Company and, upon completion of his 2 years at Illinois, he was employed by Professor Blackwelder as an assistant for field work in Kansas, Oklahoma, and Texas. This work terminated in 1921 at a time when positions in the field of oil geology were almost unobtainable and when Reed was undecided as to a definite course to follow. Previous experience and an established ability both in teaching and in geology proved to be valuable qualifications and led to an opportunity, which was accepted, to instruct at the University of Oklahoma during the year 1921–1922. It was while so engaged that Reed prepared his first three papers for publication, all dealing with problems of Oklahoma stratigraphy and sedimentation.

Ralph Reed moved to Palo Alto, California, in the summer of 1922 to accept a teaching fellowship and to continue his studies in geology at Stanford University. Sedimentary petrography and its application to stratigraphic correlation and paleogeography became his particular interest during the next 2 years and provided material for two valuable published papers and his thesis for the degree of Doctor of Philosophy in Geology which was conferred in 1924. Part of his time, however, was devoted to economic work as geologist for the then newly organized Coast Land Company, predecessor to the Marland Oil Company of California, which in turn was later merged into the present Continental Oil Company of Delaware. Upon completion of his work at Stanford, Doctor Reed accepted full-time employment with the Coast Land Company and because of his personal efforts as field geologist he played an important part in the early recognition of the tremendous economic possibilities of the Kettleman Hills structure in the San Joaquin Valley of California. The accurate work of Reed and his associates led his company to acquire leases on this structure which now include the valuable holdings of the Continental Oil Company in that field.

Reed became chief field geologist for the Marland Oil Company of California, a responsibility he held until 1929 when he resigned to accept the

position of assistant chief geologist of The Texas Company (California). He was promoted to his present position of chief geologist for that company in 1930. To the usual duties of this position there was added in 1937–1938 the task of serving as an expert witness in a pending lawsuit involving an exhaustive consideration of problems related to the geologic history of the Kettleman Hills oil field.

The geologic complexities of local California areas have been studied by geologists for almost a century. Attempts to coördinate these studies were approached in only a limited way by earlier writers. It was left for Ralph Reed to solve the baffling problems of correlation and the significance of the distribution and relations of the Granitic Basement, the Franciscan series, and the post-Jurassic Sedimentary Blanket, in his monumental work *Geology of California* published by the Association in 1933 and the equally scholarly book, *Structural Evolution of California* by R. D. Reed and J. S. Hollister, published in 1936. These volumes present the only systematic story of the geology, structural development, and paleogeographic history of this complex region and, most important, one which, because of the factual data on which it is based, will stand as the framework for future growth of our knowledge of California geology. This systematic study displays the mind of a true scientist impelled by an intense interest in earth history and equipped with every mental tool. Few craftsmen possess the facilities essential to the discovery of truth: eagerness to investigate, capacity to remember, ability to correlate, power to reason, and skill to state. These qualities are so much a part of Doctor Reed's make-up that even as an expert witness, under the stress of formal and searching questions, his expositions of physiography, sedimentation, paleontology, stratigraphy, structure, and paleogeography so faithfully disclose the continuity of history that even laymen comprehend, and so modestly reveal the rich storehouse of his knowledge that the members of his profession may well strive to emulate the standards he has set. Readers of the *Bulletin* look forward to early additional contributions from his able pen.

H. W. Hoots
C. R. McCollom

Los Angeles, California
November 21, 1939

Ralph D. Reed is convalescing at his home in Pasadena after undergoing a major operation. Because of his enforced absence from the recent Fall meeting of the Pacific Section, November 9–10, 1939, the members sent him a message of cheer, signed by 230 in attendance, to signify how much they missed the inspiration of his presence.

Memorial

DONALD CLINTON BARTON

(1889–1939)

Donald Clinton Barton died at Houston, Texas, on July 8, 1939, following his retirement from the office of president of this Association last March. He is survived by his widow, Margaret Foules Barton, his daughter, Ann Foules Barton, who continue to live in his home, "Bayou Pines," 1004 Shadder Way, at Houston, and his sister, Mrs. Helen Barton Eastman of Boston, Massachusetts. His death resulted from an acute attack of an infection of the sinuses which, in its chronic state, had afflicted him throughout the preceding two years.

In his service to this Association Donald Barton surpassed all but a few of its members. In this respect he deserved to be ranked along with Sidney Powers, who likewise died shortly after his term as president of the Association. In other respects the careers of these two outstanding petroleum geologists parallel each other. Both were New Englanders. Both were educated at Harvard. Both held the coveted Sheldon travelling fellowship. Both came to the southwest for their life's work. Both fell early under the spell of close association with that young dean of petroleum geologists, E. L. DeGolyer. Both were impatient of outward form and ceremony, yet possessed of deepest spiritual convictions. Both were studious, discerning observers, who wrote much of their own observations and inspired fellow workers also to write. But above all else, both were stamped with that forthright intellectual candor which typifies the New England scholar.

How shall we describe this quality that characterizes so many of our scientists from New England? Van Wyck Brooks has defined it in *The Flowering of New England:*

> A clear, distinct mentality, a strong distaste for nonsense, steady composure, a calm and gentle demeanour, stability, good principles, intelligence, a habit of understatement, a slow and cautious way of reasoning; contempt for extravagance, vanity and affectation; kindness of heart, purity, decorum, profound affections, filial and paternal.

Barton was born at Stow, Massachusetts, June 29, 1889, the son of George Hunt and Eva (Beede) Barton. His Puritan ancestry goes back on his father's side to Resolvit White, an older brother of Peregrine White, who came to America on the Mayflower. Barton attended Cambridge Latin School as a boy, completing the 5-year course in 4 years, and winning a scholarship bestowed upon the student who obtained the highest average grade for the whole course. His father, himself a geologist and, according to Alfred C. Lane, the first elected fellow in the Geological Society of America had been denied early schooling and had entered the Massachusetts Institute of Technology (where he subsequently became professor of geology) only after his 21st birthday. Conscious of his own early handicaps, he encouraged his son in his pursuit of an education. Before he was 10 years old, the boy attended his father on geological field trips, and while he was still in Latin School he enrolled in and passed with credit college courses in structural geology, historical geology, and mineralogy. Barton's mother, an early

W. Ward Clark Studios

DONALD CLINTON BARTON

graduate of Miss Elizabeth Peabody's school of kindergarten training and child psychology, also inspired him to scholastic diligence. His parents, then, became, in the words of his wife, "the big influence in Don's early years. They inculcated in him his independence of thought, his inner, self-sufficiency."

Barton attended Harvard College, where again he outstripped his class, completing the 4-year course, with geology as a major, in 3 years. As a member of the class of 1911 he received his A.B. in 1910, continued his studies in the graduate school, teaching geology at Radcliffe College and assisting at Harvard meantime, until he had earned his Master's degree in 1912 and his Ph.D. in 1914. At Harvard he was awarded the Sheldon travelling fellowship, one of only four geological recipients in the last 30 years, and spent the year 1913 in travel and geologic research in Europe and northern Africa. Part of the material for his doctoral thesis, "Arkose, Its Definition, Classification and Geological Significance," was obtained on this trip.

No account of Barton's education would be complete without notice of his studies of physiography and contour of coastal plains. His formative years were profoundly influenced by his experience and training under Douglas W. Johnson, whom he assisted, during college vacations, in the field investigation of shore-line processes along the coasts of New England and Long Island. Throughout his subsequent life's work Barton drew heavily upon the fruits of this association.

Beginning his professional career late in 1914, Barton first taught engineering geology at Washington University, St. Louis, Missouri. In 1916 he became field geologist for the Empire Gas and Fuel Company. From 1917 to 1919, with the American Expeditionary Forces in France, he served as private to the master signal electrician (weather forecaster), Meteorological Section, Signal Corps. In 1919, he became field geologist, and in 1923 chief geologist, of the Rycade Oil Corporation. This position he held until 1927 and during the last 3 years of his incumbency he acted also as chief of the torsion balance and magnetometer division of the Geophysical Research Corporation. Between the years 1927 and 1935 he was engaged in independent consulting practice in Houston, Texas, where he had resided since 1919, as geologist and geophysicist. In this capacity he joined the staff of the Humble Oil and Refining Company, in 1935. This association continued until his death.

Barton became a member of the Association in 1920. He was also a fellow of the Geological Society of America, a member of the American Institute of Mining and Metallurgical Engineers, Society of Economic Geologists, Society of Petroleum (Exploration) Geophysicists (ex-president), American Geophysical Union, Deutsche Geophysikalische Gesellschaft, Société Géologique de France, Institution of Petroleum Technologists, Meteorological Society, Society of Economic Paleontologists and Mineralogists, American Association for the Advancement of Science, Texas Academy of Science, Sigma Xi, Houston Geological Society, and Houston Philosophical Society.

Barton was a prodigious worker. His field expanded as he matured until it came to include geophysics as well as geology. In both branches he pioneered, boldly and with discernment. His industry and breadth of interest are attested by the length of the appended list of his publications and the range of their subject matter.

Under the inspiration and direction of E. L. DeGolyer, Barton became one of the earliest geologists to apply geophysical technique to the solution of problems of geologic structure for the benefit of American industry. In 1923 he went to Europe with this objective in mind, and in 1924, shortly after his return, the Nash dome in Brazoria County, Texas, a previously unsuspected, deeply buried salt dome, was discovered through torsion-balance surveys made under his direction. This discovery, which developed a commercial oil field, was the first of its character in the United States.

Although Barton was by birth and training so thoroughly a New Englander, his life and his work soon came to center in the south. Through the years, moreover, the softening influence of the southern environment imprinted itself over the bleaker lines of New England character. As a result, Barton acquired increasing prestige in southern industry, science, and culture. This slow metamorphosis evolved largely out of the influence of Barton's wife, Margaret Foules, a spirited southern girl, from Lafayette, Louisiana, whom he married on June 26, 1923.

Combining his studies of physiography with the revelations of his geophysical exploration, and with the evidence derived from deep-well drilling, Barton built up a comprehensive knowledge of the regional stratigraphy of the Gulf Coast of Texas and Louisiana. This knowledge, together with his unusual talents for interpretation, enabled him before any other geologist to identify and visualize the Gulf Coast geosyncline. This remarkable achievement is recorded in his paper, "Gulf Coast Geosyncline," published (with two co-authors) in 1933.

Barton was a profound student of salt domes as geologic structures; the mechanics of their growth; their tendency to "mushroom"; their "overhang"; isostatic adjustments; the balance of compaction versus uplift; the "tear-drop" effect of extreme deformation; all of these and other aspects of salt-dome geology Barton comprehended earlier and more clearly than most of his fellows did. He wrote at length on the problem himself, and, together with George Sawtelle, he edited a thick volume of salt-dome studies, the symposium on *Gulf Coast Oil Fields* published by this Association.

He was fascinated for years with the problem of the origin of oil. He attacked it with studies of the natural history of oil fields, their underground environment of oil accumulations, the evolution of oils through time, and the effects of temperature and pressure on oils in their natural habitat. In this work he drew upon the facts of chemistry, physics, and biology with originality and discrimination. His published writings on this subject form a noteworthy contribution to our knowledge of petroleum.

Not content with his own efforts in research, Barton stimulated and organized research by other workers. A logical mind and objective habits of thought equipped him admirably to recognize and outline abstract problems and to suggest appropriate methods for their solution. He identified himself actively with the research program of the National Research Council. For years he directed various research projects of this Association in petroleum geology.

Donald Barton was a member of the Unitarian Church. He was not a religious man in the popularly accepted meaning of the term. He was impatient of dogma, of fundamentalism, and even of the conventions and ceremony of modern religious creeds. Yet he was deeply religious. He was spiritually secure without the necessity for any outward label.

Barton was a founder and an early president of the Society of Petroleum Geophysicists. He contributed much to this organization. His last years were devoted to the affairs of our own Association. Indeed it may not be too much to say that his death was hastened by his labors in our behalf. Certainly his strength waned alarmingly during the period of his administration, and his death followed his retirement from office within a few months.

To a casual acquaintance Donald Barton might have appeared an austere person, devoid of a sense of humor. His pre-occupied manner and his almost brusque response to all character of approach might well engender such an impression of his character. Actually, however, he possessed a keen wit and a warm heart. Known commonly to his friends as "Doc," he was capable of close, enduring friendship, loyalty, and warm, constant affection, notwithstanding his shy, intellectual reserve. He was unyielding in defense of logical processes. While never effusive, his manner toward his colleagues was always cordial. He was sympathetic and tolerant. He was scrupulously fair, but so candid that he often seemed blunt. Much of the charm of his personality and of the reward that intimate association with him bestowed, arose from his talent for thought-provoking, instructive discussion. His death is a grievous loss to friends and to science alike.

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WALLACE E. PRATT

NEW YORK CITY
November 13, 1939

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 23, NO. 12 (DECEMBER, 1939), PP. 1897-1898

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

J. J. MAUCINI has resigned his position as district geologist for the Continental Oil Company at Wichita Falls, Texas, to become a consulting geologist. He is succeeded by P. M. MARTIN, formerly assistant geologist.

F. W. LEE, head of the geophysical section of the United States Geological Survey, addressed the Fort Worth Geological Society at a meeting held at Texas Christian University, Fort Worth, Texas.

F. T. WHITTINGHILL, JR., junior geologist with the Lion Oil Refining Company, has been transferred from Owensboro, Kentucky, to Jackson, Mississippi.

LUTHER E. KENNEDY is president of the Peters Petroleum Corporation, Tulsa, Oklahoma.

WM. T. FORAN is with the Basrah Petroleum Company, Ltd., P. O. Box 21, Basrah, Iraq.

EUGENE MCDERMOTT, president of Geophysical Serivce Incorporated, Dallas, Texas, spoke before the Tulsa Geological Society at Kendall Hall, University of Tulsa, November 6, on "Soil Surveys."

F. A. MELTON, of the University of Oklahoma, presents a paper on "Shore Zone Features" before the Tulsa Geological Society, November 20.

Effective on January 1, 1940, BASIL B. ZAVOICO is being transferred from Houston, Texas, to the headquarters of The Chase National Bank in New York City.

Whisenant and Trenchard have moved their consulting office from Mattoon, Illinois, to Evansville, Indiana. J. B. WHISENANT, 216 Chestnut Street, Evansville, represents the firm in Illinois and Indiana, and JOHN TRENCHARD is in the San Antonio, Texas, office.

New officers of the Carolina Geological Society are: president, J. H. WATKINS, The Citadel, Charleston, South Carolina; vice-president, W. J. ALEXANDER, Bryson City and Spruce Pine, North Carolina; secretary-treasurer, WILLARD BERRY, Duke University, Durham, North Carolina.

HAROLD R. WANLESS, of the department of geology, University of Illinois, delivered a paper entitled, "Sedimentation and Tectonic History of the Pennsylvanian Basins of the Eastern United States," before the Illinois Geological Society at Mattoon, October 26.

L. A. MYLIUS, consulting geologist, has moved from Vandalia to Centralia, Illinois.

G. R. SPARENBERG, recently with the Adams Oil and Gas Company at Evansville, Indiana, is now with the Sohio Producing Company, Owensboro, Kentucky.

WALDEMAR LINDGREN, internationally known geologist and many years head of the department of geology of Massachusetts Institute of Technology, died on November 3, at Brookline, Massachusetts, aged 79 years.

The East Texas Geological Society, Tyler, Texas, elected the following officers, October 9: president, E. M. RICE, Pure Oil Company; vice-president, FRANK R. DENTON, Stanolind Oil and Gas Company; secretary-treasurer, C. I. ALEXANDER, Magnolia Petroleum Company; member of executive committee, H. J. MCCLELLAN, Humble Oil and Refining Company.

HENRY CARTER REA is in the employ of the Seaboard Oil Company, Gulf States Building, Dallas, Texas.

DWIGHT E. WARD, formerly with the Standard Oil Company of Louisiana, at Texarkana, is now with the Carter Oil Company at Canton, Mississippi.

ANATOLE SAFONOV, recently with the Ohio Oil Company in Oklahoma and Missouri, is on the geological staff of the United Gas Company, Houston, Texas.

JOHN D. HENDERSON is geologist for the Lion Oil Refining Company at Jackson, Mississippi.

FRANK N. BLANCHARD, JR., of the Skelly Oil Company, Pampa, Texas, has been elected secretary-treasurer of the Panhandle Geological Society.

STANLEY C. HEROLD, consulting geologist, Los Angeles, California, presented a paper before the Petroleum Division of the A.I.M.E. at Los Angeles, October 19–20, entitled, "Must We Look for a New Reservoir Control?"

SAM GRINSFELDER is general manager of the Union Oil Company of California district office at Houston, Texas.

B. W. BEEBE, recently district geologist for the British American Oil Producing Company at Wichita, is connected with Lerke and Whortan, consulting geologists of Wichita, Kansas.

CARL WEIDMANN has a new address: Apartado 643, Ciudad Trujillo, Republica Dominica.

F. A. SUTTON is with the Lago Petroleum Corporation, Apartado 172, Maracaibo, Venezuela.

K. D. WHITE has moved from The Hague to the Standard Oil Company of Egypt, 22 Sharia Kasr el Nil, Cairo, Egypt.

MCCOMBS HARDY, consulting geologist, has moved from Little Rock, Arkansas, to Scottsville, Kentucky.

E. F. BOEHMS, of the Forest Development Company, recently at Abilene, is now at 904 Milam Building, San Antonio, Texas.

FREDERICK G. CLAPP, consulting geologist, 50 Church Street, New York, gave an illustrated lecture on Afghanistan at the University of Iowa, October 20.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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VOLUME 23

JANUARY—DECEMBER 1939

PART I

PAGES 1-982

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BOX 979, TULSA, OKLAHOMA

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Tulsa, Oklahoma

EDGAR W. OWEN, *Secretary-Treasurer*
San Antonio, Texas

WALTER A. VER WIEBE, *Editor*
Wichita, Kansas

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(Representatives' terms expire immediately after annual meetings of the years shown in parentheses)

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Canada
Harry M. Hunter (1941), Calgary, Canada
Capital
Arthur A. Baker (1940), Washington, D. C.
Dallas
P. W. McFarland (1940), Dallas, Tex.
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New York
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Pacific Coast
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Harold K. Armstrong (1941), Los Angeles, Calif.
Herschel L. Driver (1941), Los Angeles, Calif.
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Shreveport
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Southeast Gulf
James H. McGuirt (1941), University, La.
So. Permian Basin
Ronald K. DeFord (1941), Midland, Tex.
South Texas
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Harry H. Nowlan (1941), San Antonio, Tex.
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PART I

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NUMBER 6

Recent Developments

ERRATA

Pages 214–15, Figure 1: Pedras Lumbre should be *Piedra Lumbre;* Ezell, *Ezzell;* Loma Novita, *Loma Novia;* Callihan, *Calliham;* Sarnoca, *Sarnosa;* Amargosa, *Armagosa;* Charamusa, *Charamousca;* Telfener, *Telferner;* Mestinas, *Las Mestenas;* Henne-Winch-Ferris, *Henne-Winch-Farris;* Alta Vista, *Loma Alta*, and Adams well in Jim Wells County should be slightly northwest of point of junction of Jim Wells, Kleberg, and Nueces counties.

Page 216, columns 3 and 4: Markam should be *Markham;* Telfener, *Telferner.*

Page 523, Figure 2: Redrock Mt. (northeast from center of map) should be shown as *Basement Complex* instead of Eocene.

Page 532, Table I, column 3: last 5 lines describing upper Miocene in "Easternmost Ventura Basin" should read: Mint Canyon yielding *Hipparion*, *Merychippus*, and *Protohippus* in its upper third and *Parahippus* (?) in its lower third.

Page 604, line 12: "Orchard dome, Fort Bend" should be *Hawkinsville dome, Matagorda.*

Lines 13–14: "Hawkinsville dome, Matagorda" should be *Orchard dome, Fort Bend.*

Page 605: section at top of page should be captioned as Figure 2, illustrating Hawkinsville dome; and section at bottom of page should be captioned as Figure 1, illustrating Orchard dome.

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ERRATA

Page 1122, Table III: University of Illinois should be included in the list as No. 17 with 42 undergraduates.

Table V: University of Illinois should be included as No. 19 with 76 undergraduates and graduates.

Page 1173, Figure 10: Pruess should be *Preuss.*

Page 1175, lines 8 and 18: Pruess should be *Preuss.*

Page 1176, Figure 13, column 3: Pruess should be *Preuss.*

Page 1235, center headings: Fusion should be *Fuson;* Minnewasta should be *Minnewaste;* Minnekata should be *Minnekahta.*

Page 1453, line 14 from bottom: "TRIASSIC (38)" belongs at end of line above.

Page 1454: measurements 130, 140, and 60 under "MADISON formation" should be sub-headings under "330 Lower member. . . ."

Page 1472, line 14 from bottom: "Figure 19" should read *Figure 18.*

Page 1482: "Axis? (L. S.)" should be deleted from section labelled "Stage 2."

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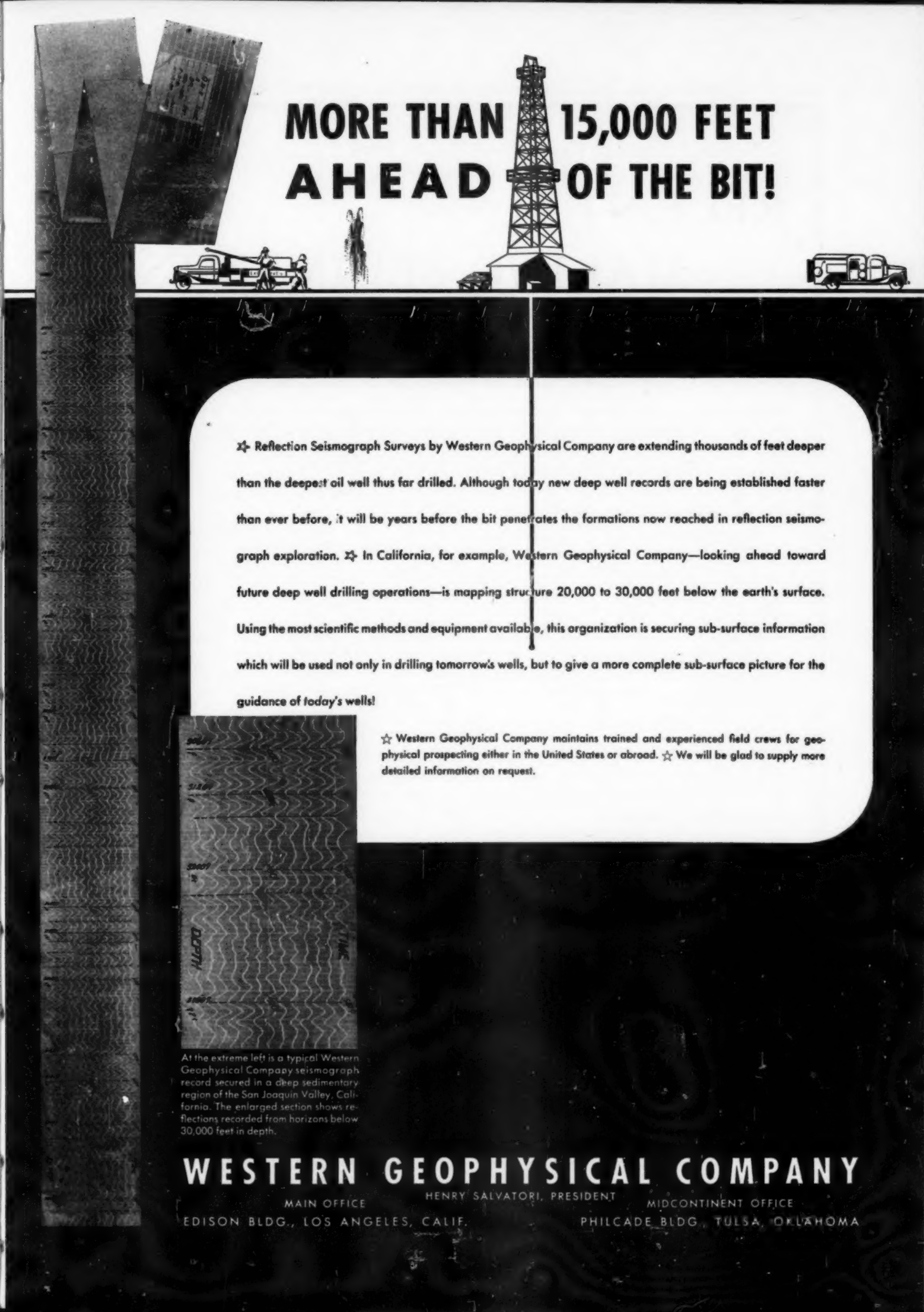
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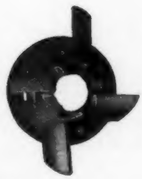

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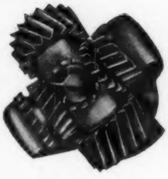

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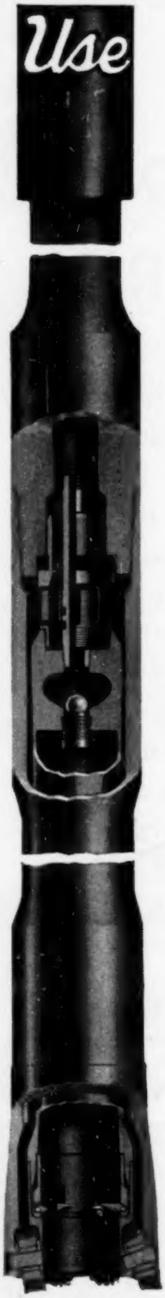

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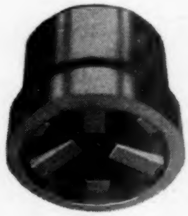

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